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PHARMACEUTICAL BOTANY

YOUNGKEN

BY THE SAME AUTHOR

A TEXT BOOK

OF

PHARMACOGNOSY

2d Edition

Octavo. xiii + 700 pages, 301 Illustrations
Containing about 600 Figures

P. BLAKISTON'S SON & CO.
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The Henbane (*Hyoscyamus niger* Linné.), a member of the Nightshade family, whose leaves, with or without the tops, constitute the official drug Hyoscyamus and are a source of the valuable medicinal alkaloids, hyoscyamine and scopolamine.

(*Frontispiece*)

PHARMACEUTICAL BOTANY

A Text Book of College Botany with Pharmaceutical and Medical Applications. Especially Adapted for the Use of Students of Pharmacy and Medicine and as a Reference for Pharmacists, Chemists and Students in Structural and Systematic Botany

WK 7550

BY

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FIFTH EDITION, REVISED AND ENLARGED

WITH 387 ILLUSTRATIONS

AND GLOSSARY OF BOTANICAL TERMS

PHILADELPHIA

P. BLAKISTON'S SON & CO.

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TO

MY WIFE

Clara Eastman Youngken

74110

PREFACE TO THE FIFTH EDITION

Since the fourth edition of this volume was issued, there have been notable advances in the development of pharmaceutical botany. A new United States Pharmacopœia and a new National Formulary have appeared. The Commonwealth Fund Educational Research Committee has rendered its report on the study of Pharmacy from the functional standpoint and in it the findings of its botanical studies.

These events alone made some additions and alterations of the text necessary. But the writer has gone further. A large part of the text has been rearranged, rewritten and amplified with a view toward improving the clarity of certain portions of the subject matter, and extending its adaptability.

More than a hundred pages of new matter and one hundred and twenty-four new figures comprising original drawings and photographs and borrowed cuts from classic works have been added, and some of the older illustrations have been replaced by better ones.

The botanical findings of the Commonwealth Fund Educational Research Committee have been incorporated, although the text is not limited to these.

Sufficient new information has been added to make the book a distinct improvement over the former editions, and this should make it better for use in professional pharmaceutical colleges and for the courses in botany now prescribed for Pre-medical students in academic colleges, as well as for students in Bachelor of Science courses in colleges of pharmacy.

The table of contents clearly indicates the changes made in the form of the text which now contains twenty-five chapters; an increase of sixteen over the previous edition.

It is believed the increased number of chapters and their new sequence will be found convenient for teachers in assigning work alike for study and collateral reading.

It is hoped that the new edition will also be of value to research students in various fields of botany, since it furnishes in the classified list of reference works a summary of a large amount of literature of the subject.

H. W. Y.

PREFACE TO THE FOURTH EDITION

The value of a thorough systematic training in Botany with emphasis upon the structural and taxonomic aspects of this science is now generally recognized as a prerequisite to the proper comprehension of problems in pharmacognosy and materia medica. But apart from the direct relation of such training to these and other applied fields, Botany *per se* stands out preeminently as a cultural subject and, when presented with laboratory work, is of great value in developing, in students, the power of observation.

In preparing the new edition of this text-book, the author has primarily kept in mind the needs of the pharmaceutical student but he has not been unmindful of its use by students of academic colleges and accordingly has increased the scope of the work.

Fifty-three new pages of subject matter and 25 illustrations have been added. Chapter I on "Fundamental Considerations" has been augmented by the inclusion of a list of standard micro-chemical reagents used in food and drug work together with formulæ for their preparation. Chapter VII on "Plant Organs and Organisms" has been lengthened by 23 pages of new subject matter. Among the outstanding features of its revision may be mentioned the introduction of considerable more plant physiology as well as new drawings and photographs, most of which are original.

There has been an amplification of the subject matter of roots, rhizomes, leaves, seeds and seedlings including data on soil and water relation, diffusion, osmosis, osmosis applied to root hairs, turgor, plasmolysis, essential and non-essential elements absorbed by root hairs, transpiration and the histology of a type of Monocotyl rhizome. New plates illustrating the gross structure of Monocotyl and Dicotyl seeds and of seedlings are introduced for the first time. Chapter IX on Ecology has been lengthened by 20 pages and several illustrations on Carnivorous plants.

Every part of the work has been carefully revised and brought up to date. As in former editions, the index has been so planned as to make the information contained in this book readily accessible.

To the authors from whom cuts were borrowed, the writer's thanks are due.

H. W. Y.

PREFACE TO THE THIRD EDITION

The author has first endeavored to present in a clear, systematic way those fundamental principles of structural and taxonomic botany which serve as a key to the approach of pharmacognic problems. But he has not been unmindful that the use of the work has extended to academic institutions and, so, in this edition, has broadened the scope of the former text. To this end about ninety additional pages of subject matter have been introduced. Several old cuts have been removed. Forty-three new ones have been inserted. Hypothetical discussions have been avoided which saves time for the reader.

The arrangement and plan of the chapters are similar to that of the former edition, in order to adapt the work to several methods of approach. Chapter I on "Fundamental Considerations" has been augmented by treatises on Botanical Nomenclature, Paraffine and Celloidin Imbedding, Sectioning, Staining and Mounting, Microtomes and other information dealing with the preparation of materials for microscopic examination.

Ten pages have been added to Chapter V on Cytology. Under "Protoplasm and its Properties," six pages have been written on the subject of Irritability and Irritable Reactions. Under "Non-Protoplasmic Cell Contents" several additional commercial starches are discussed and two original plates on starch grains added. Additional cuts on Collenchyma, Stone Cells, Sclerenchyma Fibers, Trichomes and Fibrovascular Bundles have been inserted in Chapter VI.

Nine additional pages of subject matter and illustrations have been added to Chapter VII. Original figures of all of the important types of fruits appear here for the first time.

Chapter VIII on "Taxonomy" has been increased by seven pages of new data, and the whole former text carefully revised.

Chapter IX on "Ecology" has been newly introduced as has also a Glossary of Botanical Terms. The index has been so planned as to make the information contained in this book readily accessible.

To the authors of works from which cuts were borrowed the writer's thanks are due.

H. W. Y.

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PHARMACEUTICAL BOTANY

CHAPTER I

THE SCOPE OF BOTANY

Botany is the science which treats of plants. Plants are living things or organisms belonging to one of the two great kingdoms of living things, called the **Vegetable** or **Plant Kingdom.** The other kingdom of living creatures is that made up of animals and called the **Animal Kingdom.** The science which treats of animals is called **Zoölogy.** Botany and Zoölogy collectively constitute the branch of natural science called **Biology,** the science which seeks to inquire into all living things.

The term botany is derived from the Greek word *βοτάνη* meaning pasture, grass, or fodder. Man's first inquiry into plants was undoubtedly prompted by his instinct to seek food, and history records the first pursuit of botany as a science by the ancient Chaldeans, Egyptians and Greeks who cultivated it particularly in relation to sources of food supply.

Later man found that some plants possessed medicinal properties and interest was next focused in the direction of plants as sources of medicines. Probably the greatest of the early pioneers in this field was Theophrastus, a Greek philosopher, who lived between 370 and 285 B.C. He wrote ten books on the *History of Plants* in which about 500 plants used in the treatment of various diseases are described. Attention was next concentrated upon the classification of plants and gradually investigations followed on their structure, functions, habits, relationships, diseases, etc., until to-day the scope of botanical study embraces every kind of inquiry about plants.

The field of botany has thus developed many specialties or departments of inquiry.

DEPARTMENTS OF BOTANICAL INQUIRY

1. **Plant Morphology** treats of the parts, or structure of plants. It is divided into:

(*a*) **Macromorphology** or **Gross Anatomy** which deals with the external characters of plants and of their parts or organs. (*b*) **Micromorphology** or **Histology** which considers the minute or microscopical structure of plants and plant tissues; (*c*) **Cytology** which treats of plant cells and their contents; and (*d*) **Embryology** which treats of the stages of development of the young plant or *embryo* up until it germinates or sprouts from the seed.

2. **Plant Physiology** deals with the study of the life processes or functions of plants. It explains how the various parts of plants perform their work of nutrition, growth, reproduction, and the preparation of food for the support of animal life from substances not adapted to that use.

3. **Taxonomy of Plants** or **Systematic Botany** considers the classification or arrangement of plants in groups in accordance with their relationships to one another. It also is concerned with the accurate description and the naming of plants. All of the plants found growing in a certain region constitute the *Flora* of that region.

4. **Plant Ecology** treats of plants and their parts in relation to their environment, *i.e.* to soil, moisture supply, temperature, light and other plants and animals.

5. **Plant Genetics** seeks to account for the resemblances and differences shown by plants related by descent.

6. **Plant Pathology** or **Phytopathology** treats of diseases of plants.

7. **Plant Geography** or **Phytogeography** treats of the distribution of plants upon the earth. The center of distribution for each species of plant is the *habitat* or the original source from which it spreads, often over widely distant regions. When plants grow in their native countries they are said to be *indigenous* to those regions. When they grow in a locality other than their original home they are said to be *naturalized.*

8. **Geological Botany** or **Phytopalæontology** treats of plants of former ages of the earth's history traceable in their fossil remains.

9. **Economic** or **Applied Botany** deals with the science from a practical standpoint, showing the special adaptation of the vegetable kingdom to the needs of everyday life. It comprises a number of subdivisions, viz.: **Pharmaceutical Botany,** or the botany of drug and poisonous plants; **Bacteriology,** which treats of microörganisms called bacteria; **Pharmacognosy** which treats of the history, commerce, selection, identification, valuation and preservation of crude drugs and other raw materials of plant and animal origin; **Agricultural Botany** or **Agronomy,** which treats of crop plants; **Horticulture,** which treats of the cultivation of garden and orchard plants; **Forestry** which treats of the management of forests and of timber plants; **Plant Breeding** or the application of principles of selection to the growing of improved races of plants. All of these subdivisions interlock closely with departments of pure botanical inquiry and no training in either of them can be considered sound without the assimilation of the broad underlying principles of morphology, taxonomy and physiology.

CHAPTER II

THE GENERAL CHARACTERISTICS OF PLANTS

If we look about in nature we are confronted at once with many kinds of living objects called plants, but the more familiar ones to the beginner in Botany are the higher green plants such as the common herbs, shrubs and trees of field, meadow or woodland. Each of these is a living entity or **organism** which has descended from a parent or parents with an ancestry and which is capable of carrying out all of the life processes which are essential to its existence and to the perpetuation of its species or kind. Each is composed of **organs** or parts whose life processes are separate but mutually dependent and essential to the healthful maintenance of the individual, and the continuation of its kind.

These organs are the **roots, stems, leaves, flowers, fruits** and **seeds.** The roots, stems and leaves are so constructed as to carry out the **vegetative processes,** *i.e.*, the activities which have to do with the maintenance and protection of the individual, whereas the flowers, fruits and seeds are structurally adapted to the carrying out of the **reproductive processes** or the activities which have to do with the continuance of the species of the plant of which the individual is a representative.

The **root** grows down into the soil and anchors the plant, absorbs water with nutrient salts in solution and stores food to tide the plant over the season when growth activity is suspended. The **stem** grows upward and so represents the ascending axis of the plant. Its processes are those of bearing leaves and branches, conducting sap containing nutrient materials from roots to leaves and vice versa. The **green leaves,** representing outgrowths of the stem, are spread out to the sun's rays for carrying out the process of manufacturing complex food from simple inorganic materials absorbed from the soil and the air. The **flowers** are equipped with sexual organs called

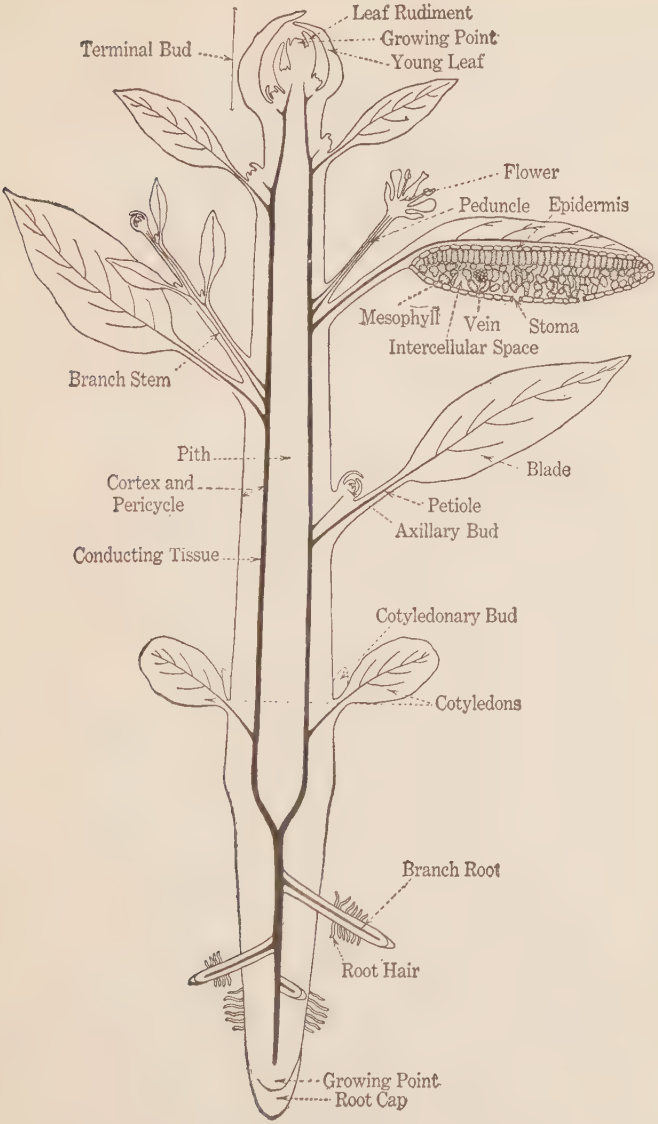

FIG. 1.—Diagram of the body of a seed plant, showing its principal parts. (*From Robbins, after Holman and Robbins.*)

stamens (male organs) and **pistils** (female organs) and are so constructed as to bring about fertilization. The **fruits** which follow the flowers function to form and disseminate the seeds. The **seeds** serve to carry a young plant or embryo which has separated from its parent in its dormant stage to the soil and so function to spread the plant. In addition to the life processes noted, these plant organs carry out activities necessary for their own maintenance such as transportation of food materials, growth (increase in size), respiration (the breaking down of carbohydrates accompanied by the taking in of oxygen and giving off of carbon dioxide), and assimilation (the changing of food materials into living matter).

Just as the plant organism is made up of organs which are visible to the unaided eye, so each of these organs is made up of parts called **tissues,** but the tissues are visible only with the aid of a simple or compound microscope.

Some of the **tissues** in the stem for instance, are the outer protective tissue or **epidermis,** the soft region beneath the epidermis and in the pith of the stem or **parenchyma,** the woody portion which gives support to the stem or **sclerenchyma** (stony tissue), the water tubes which conduct sap upward or **tracheary tissue.**

Other plant organs are also differentiated into secondary parts or tissues which have been set aside to perform some definite kind of work in the economy of the organs. The healthful performance of the functions of an organ depends upon the harmonious relation existing between the tissues of which it is composed.

Every tissue, when examined microscopically, is seen to be composed of numerous units of similar form which are in intimate relation one with another. These appear like small compartments or chambers, separated from each other by walls and have been termed **cells.** It will be noted that every cell possesses contents.

While these cell contents vary in character depending upon the cell examined, every living cell contains a viscid, granular, mobile, jelly-like substance in which life resides. This is called **protoplasm** or living matter. It is this living substance which constructs the cells or fundamental units of which the plant body is formed, and carries out all of the life processes of the plant.

The herbs, shrubs and trees discussed in the preceding paragraphs represent but few of the vast array of forms which make up the Plant Kingdom. Many additional kinds of plants varying in form, habitat and method of living will be discussed in the chapters to follow, but in order that the student may approach the study of these with better understanding, it seems necessary, at this point, to make some general comment on the larger groups of plants.

Groups of Plants.—There are four great divisions in the Plant Kingdom. The lowest of these in scale of organization is the **Thallophyta** or Thallophytes [Gk. *thallos*, a young branch; *phyton*, plant]. They have been so named because their bodies, each of which is called a *thallus*, show no differentiation into roots, stems and leaves. To this division belong the sub-divisions **Algae** and **Fungi.** The **Algae** include the green and blue-green scums which occur in stagnant pools, ditches and in running streams, the diatoms and the green, brown and red seaweeds. The **Fungi** include the bacteria or minute germs of decay and disease, the slime molds, the yeasts, molds which occur on bread, cheese, fleshy drugs, some pharmaceutical preparations, etc., the water molds, some of which attack the gills of fishes, the mildews, the mushrooms and toadstools, and many forms which cause plant diseases, such as the smuts, rusts, chestnut tree blight, ergot of rye, etc. There is another subdivision of Thallophytes called **Lichens** which comprises the leathery-like growths which occur on the bark of trees, on rocks and the soil of woodland. They are peculiar plants in that each represents a living together of an alga and a fungus.

Next to the Thallophytes in order of ascending complexity of structure come the **Bryophyta** or Bryophytes [Gk. *bryon*, moss; *phyton*, plant]. This division includes the liverworts or **Hepaticæ** and the mosses or **Musci.** The liverworts are small, leaf-like plants which occur on moist earth and in water. Some of them are thought to be descendants of forms which were the first plants to take up a land existence. The mosses include pale green forms of swampy ground and bogs called peat mosses, the black mosses of siliceous rock, and the bright green or common mosses which so conspicuously carpet portions of our forests and rocks.

The next highest division is that known as the **Pteridophyta** or Pteridophytes [Gk. *pteris*, fern; *phyton*, plant] which have as their representatives the **Club Mosses, Horsetails** or Scouring Rushes and the **Ferns.** While most of these are low growing terrestial plants, a few forms are aquatic in habit and some of the tropical ferns assume tree-like form.

The Thallophytes, Bryophytes and Pteridophytes are collectively termed the **Cryptogams** [Gk. *cryptos*, hidden; *gamos*, marriage or union], since it was formerly believed that the sexual organs of these plants were obscure. They reproduce by spores, and, for the greater number, also by sexual reproduction.

The most highly evolved group of plants is that of the seed plants or **Spermatophyta** [Gk. *sperma*, seed; *phyton*, plant] of which the more familiar herbs, bushes, vines and trees are examples. The Spermatophytes are also called the **Phanerogams** [Gk. *phaneros*, evident; *gamos*, union], because it was formerly believed that they alone showed evident sexual organs. They are characterized by possessing flowers and producing seeds.

The **Spermatophytes** include two sub-divisions, namely the **Gymnosperms** and the **Angiosperms.** The Gymnosperms [Gk. *gymnos*, naked; *sperma*, seed] have their seeds uncovered. They include such plants as the pines, spruces, firs, hemlocks, larches, yews, junipers, cedars, arbor vitæ, the cycads, ginkgos, gnetums and ephedras.

The **Angiosperms** [Gk. *angeion*, vessel; *sperma*, seed] have their seeds enclosed within the seed vessel or fruit wall. They include two sub-groups or classes, namely, the **Monocotyledons** and the **Dicotyledons.** The **Monocotyledons** [Gk. *monos*, alone; *kotyledon*, a cup-shaped hollow] are represented by the cat-tails, grasses, sedges, lilies, palms, bananas, gingers, orchids, etc. They have a single seed-leaf or cotyledon, mostly parallel veined leaves and the parts of their flowers are in threes.

The **Dicotyledons** [Gk. *di*, two; *kotyledon*, a cup-shaped hollow] are represented by such forms as the willows, poplars, maples, oaks, chestnuts, geraniums, violets, cherries, roses, beans, asters, etc. They have two seed-leaves or cotyledons, netted veined leaves, and the parts of their flowers are in fours and fives.

Every seed plant normally comes from an egg cell which has been fertilized within the ovule of a flower. The fertilized egg divides and redivides to form at first a nearly uniform mass of cells. As these cells continue to multiply a process early becomes manifest. This process is called **physiological division of labor** and consists of the apportioning of separate kinds of work to different parts of the same organism. The result of the changes occurring in physiological division of labor is called **differentiation.** As the cells continue to increase, unequal growth takes place among them and, in time, they become differentiated to form a young seed plant or embryo. The embryo lies within the ovule which by this time has ripened to form with the embryo the structure called the seed.

Upon reaching suitable soil the seed absorbs water and its embryo swells and sprouts forth or germinates, forming a young seedling plantlet with roots, green foliage leaves and stem. Eventually, through further growth and differentiation, a mature adult plant is developed which bears flowers in which female sexual cells or eggs and male sexual cells or sperms are produced. The sperm unites with the egg, fertilizing it, thus starting a new cycle. This process is continued from generation to generation.

CHAPTER III

THE MICROSCOPE

A **microscope** is an optical instrument, consisting of a lens, or combination of lenses, for making an enlarged image of an object which is too minute to be viewed by the naked eye.

Microscopes are of 3 kinds, viz.: simple, dissecting and compound.

THE SIMPLE MICROSCOPE

This consists simply of a convex lens or several combined into a system and appropriately mounted. A good example of a simple microscope is a reading glass. This type of simple microscope is valuable in field work, in the examination of dried herbarium material or the external characters of crude drugs, where only a low magnification of the object is required.

THE DISSECTING MICROSCOPE

But when flowers or other plant parts are to be dissected, it is necessary to have both hands free. To meet this need various forms of stands have been devised which have been combined with an arm and lens to constitute what are known as "Dissecting Microscopes." One of the simpler forms of these is shown in Fig. 2. It consists of a metal stand with convenient hand rests; a glass stage plate, full size, on which the object to be dissected is placed; a double faced mirror adjustable for reflecting light from various angles, the concave face for concentrating all of the light at the plane of the object. A jointed lens arm is carried on a rack-and-pinion focusing adjustment having ample range to suit a variety of thicknesses of objects. A black-and-white metal stage plate serves for use as a contrast background.

THE COMPOUND MICROSCOPE

A. *Its construction:*

The principal parts of a compound microscope are:

1. The *base*, generally horseshoe shaped, which rests on the table.

2. The *pillar*, an upright bar, which is attached to the base below, supports the rest of the instrument and incorporates the inclination joint.

3. The *stage*, a horizontal shelf upon which is placed the preparation or slide to be examined. The stage is perforated in the center for transmitting light reflected up by the mirror. On the stage are two clips for holding the glass slide.

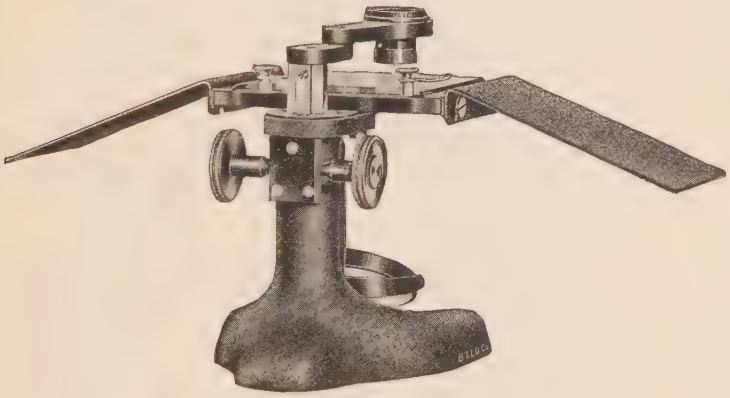

FIG. 2.—A dissecting microscope. Description in text.

4. The *mirror*, situated below the stage, by which the light is reflected upward through the opening in the stage. The mirror generally has two faces; the one is plane for initial light intensity, the other concave for concentration of light on the object.

5. The *diaphragm*, inserted in the opening of the stage or attached to its lower face, and used to regulate the amount of light reflected by the mirror.

6. The *body tube*, a cylinder which holds the *draw tube* and *lenses* and moves up and down perpendicularly above the opening in the stage. The tube is raised or lowered either by sliding it back and forth with a twisting movement or by a *rack and pinion* mechanism.

The latter is called the *coarse adjustment* and is used for finding the focus.

7. The *fine adjustment*, a micrometer screw back of the tube, which, on being turned, produces a very slow motion of the entire

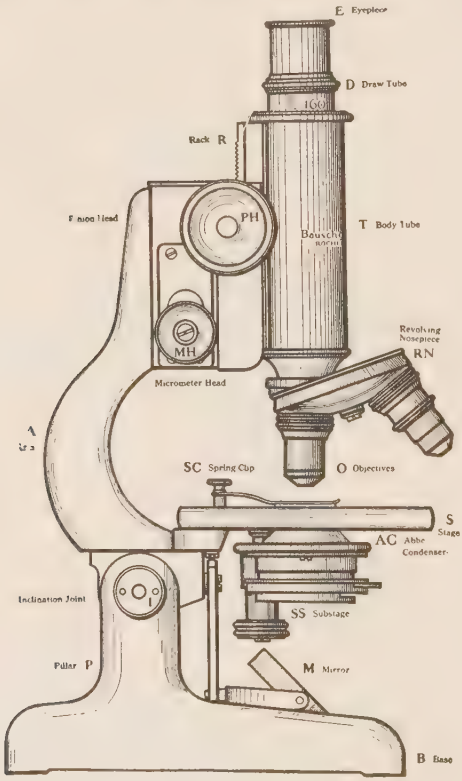

FIG. 3.—Illustrating the parts of a compound microscope.

framework which holds the body tube. It permits exact focusing of the higher power lenses.

8. The *oculars* or *eyepieces* which slip into the upper end of the *draw tube*. Each of these consist of two plano-convex lenses, the lower one being the larger and known as the *collective* or *field lens* because it increases the field of vision. The upper or smaller lens is

called the *eye lens*. It magnifies the image formed by the objective. Midway between the field and eye lens is a *perforated diaphragm*,

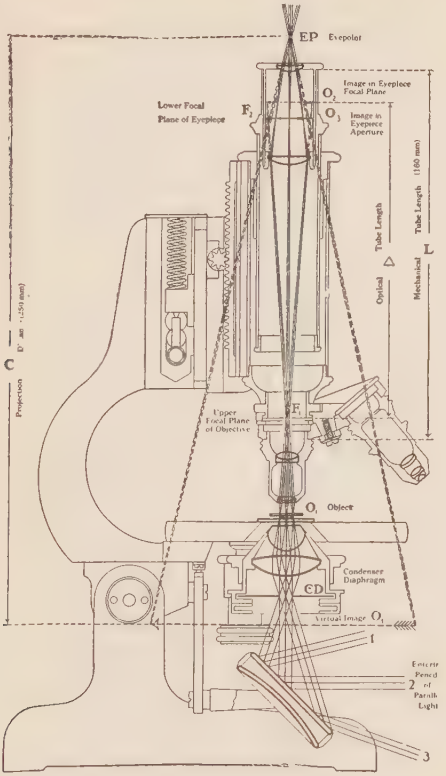

FIG. 4.—Diagram illustrating optics of a compound microscope in use. F_1, Upper focal plane of objective; F_2, Lower focal plane of eyepiece; Δ, Optical tube length = distance between F_1 and F_2; O_1, object; O_2, real image in F_2, transposed by the collective lens, to O_3, real image in eyepiece diaphragm; O_4, virtual image formed at the projection distance C, 250 mm. from EP, eyepoint; CD, condenser diaphragm; L, mechanical tube length (160 mm.); 1, 2, 3, three pencils of parallel light coming from different points of a distant illuminant, for instance, a white cloud, which illuminate three different points of the object. (*Courtesy of Bausch and Lamb Optical Co.*)

the object of which is to cut out edge rays from the image. It determines the size of the field of view.

According to the system adopted by the maker, oculars are designated by numbers, as 1, 2, 3, 4, etc., or by figures which represent focal lengths, and magnification numbers.

9. The *objectives*, which screw into the bottom of the body tube or nose piece. They consist of a system of two, three or more lenses, some of which are simple, others compounded of a convex crown lens and a concave flint lens. Objectives like oculars are usually designated by numbers or by figures as $\frac{1}{12}$, $\frac{1}{6}$, $\frac{2}{3}$, etc., or in millimeters, as 2 mm., 4 mm., 16 mm., which represent focal lengths or numbers, as 97, 45, 10, etc. which indicate the magnification of the objective alone.

The smaller the number or fraction representing the focal length of an objective, the greater is its magnifying power.

Objectives are either *dry* lenses or *immersion* lenses. If an air space be present between the tip of the objective and the object, the lens is called a *dry* one; if a liquid is present between the tip of the objective and the object, the lens is called an *immersion* lens. If this liquid be oil, the objective is called an *oil immersion objective;* if water, a *water immersion objective.*

The important properties of the microscope objective are: *Numerical aperture* (*N.A.*) which is the index of resolving power. Resolving power is that by which two small elements in the structure of an object and which are only a short distance apart are distinctly separated.

The higher the N.A. the greater the resolving power of the objective and the finer the detail it can reveal.

N.A. equal N times sin u

wherein

n = the lowest refractive index that appears between the object and the front of the objective.

u = half the angular aperture of the objective.

The degree of angle of illumination directly affects resolving power up to a maximum resulting from filling the aperture of the objective with light.

A 4 mm., 0.85 N.A. objective will resolve lines separated by distance ranging between 0.00062 and 0.00031, dependent upon the

aperture employed. For a 4 mm., 0.65 N.A. objective the limiting values are 0.00081 and 0.000405.

Two objectives of the same equivalent focal length (E.F.) and the same N.A. should show the same illuminated area in the back lens,

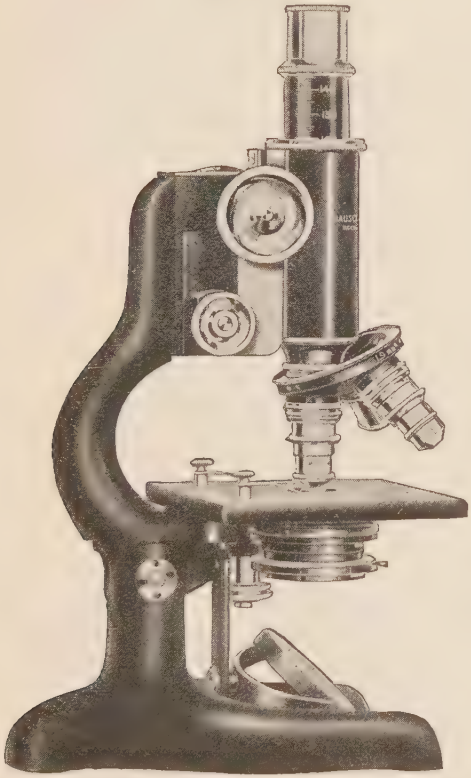

FIG. 5.—A modern compound microscope with triple nose piece, side fine adjustment and substage.

when viewed without an eyepiece and illuminated with the widest cone of light they can take in.

It also is evident that an objective cannot show its full efficiency if it is not used with a condenser of an N.A. large enough to fill the back of the objective with light.

Depth of Focus. -Depth of focus (known also as depth of sharpness of penetration) depends on the N.A. and the magnification and is inversely proportional to both. The higher the N.A. and the higher the magnification, the less the depth of focus. An increase of the depth of focus, for instance, by inserting diaphragms above the back lens of the objective must necessarily decrease the effective diameter of the back lens and thus decrease the N.A., thereby lowering the efficiency of the objective.

To comply with different requirements in this respect the makers offer two 4 mm. objectives, whose depths of focus, when used with the same magnification, are in the ratio of 3:4.

It should be borne in mind that the finer the definition of an objective the more sensitive it is to incorrect focusing and to slight changes of the fine adjustment screw. This means less depth of focus. Objectives that show greater depth of focus than others of the same N.A. cannot be well corrected.

Working distance of an objective is sometimes confused with the equivalent focus. It varies for different powers being disproportionately less for high powers, and is measured from the front of the objective to the upper surface of the cover glass. For instance, the high dry objective (4 mm. e.f. 0.65 N.A.) has a working distance of 0.6 mm.

Some microscopes are fitted up with a *nose-piece*, capable of carrying two, three, or four objectives, which may be revolved into place at the lower end of the body tube. Others have a *condenser* which is employed to concentrate the light upon the object examined.

B. *Its use:*

1. Place the microscope on the table with the pillar nearest you.

2. Screw the objectives into the nose piece and slip an ocular into the upper end, if not already on instrument. Turn the lowest power objective into position.

3. Find the light by looking into the ocular (eye piece) and at the same time turning the mirror at such an angle that it reflects light from the window or lamp up through the opening in the stage to the objective. When opaque objects are to be illuminated, a stronger illumination is required than that usually afforded by an ordinary laboratory lamp or by the light from a window. For this purpose

a microscope lamp, such as the Bausch and Lomb No. 4578 (see Fig. 6) is very satisfactory. Mirrors have two faces, a plane and a concave. Use the concave unless employing the condenser, when the plane mirror should always be used.

4. Regulate the quantity of light by the diaphragm. If too bright it must be cut off somewhat. The higher powers require brighter light than the lower; the oil immersion full opening.

5. Place the slide on the stage in a horizontal position with the object over the middle of the opening through which light is thrown from the mirror.

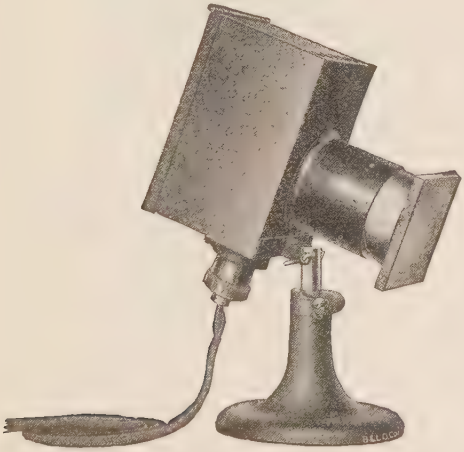

FIG. 6.—Microscope lamp, useful in illuminating opaque objects.

6. With the lower power in position quite close to the object, move the coarse adjustment upward until either the object or small solid particles on the slide appear distinctly, which means that the lenses are *in focus*. (If two objectives only accompany your instrument, the low power is the shorter one.) The object, if not under the lens, may now be brought into the field by moving the slide back and forth very slowly while looking through the ocular. To improve the focus, slowly turn the fine adjustment screw.

7. To focus with the high-power objective, first find the object with the low power and arrange in the center of the field. Put clips

on slide without moving it. Raise the body tube by means of the coarse adjustment. Then turn the high-power objective into position. Lower the body tube carrying the objective until the objec-

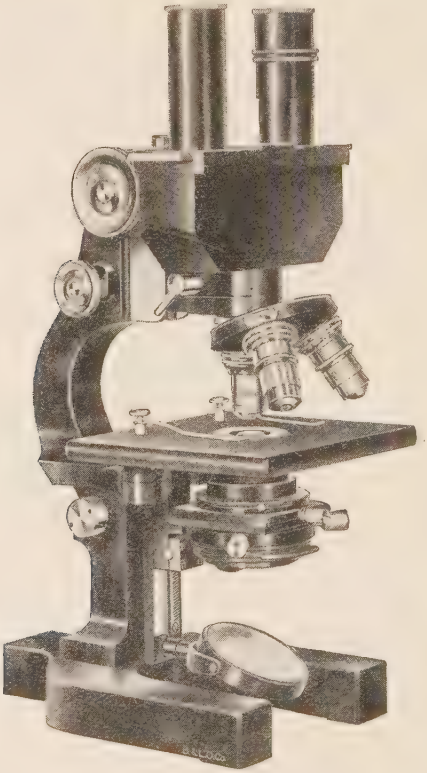

FIG. 7.—Binocular microscope. This is a compound microscope with a binocular body designed to relieve eyestrain for those doing microscopical research work or otherwise engaged for prolonged periods with the microscope. Note the parallel position of the eyepiece tubes which are adjustable for interpupillary distance by means of a compound slide, with the distance indicated on a numbered millimeter scale for future guidance. One tube has a spiral adjustment for correcting any difference in vision existing between the two eyes. The instrument shown is that designated CAE of the Bausch and Lomb Optical Co.

tive front lens nearly touches the cover glass. A slight movement of the fine adjustment should show the object clearly. Never focus down with the high-power objective while looking through the ocular

because of the danger of pressing it into the cover glass and the risk of ruining the delicately mounted lenses.

Accustom yourself to use both eyes indifferently and always keep both eyes open. If right handed, observe with the left eye, as it is more convenient in making drawings.

9. When the *oil immersion objective* is to be used, a small drop of immersion oil (slightly evaporated cedar oil) should be placed on the cover glass directly above the object and the body tube should be run down with the coarse adjustment until the front lens of the immersion objective enters the drop and comes almost into contact with the cover glass. This should be done while watching the objective. Then look through the ocular and draw the objective up with the fine adjustment until the object comes into focus.

RULES FOR THE CARE OF THE MICROSCOPE

1. In carrying the microscope to or from your table, grasp it firmly by the pillar and hold in an erect position, so that the ocular which is fitted loosely into the draw tube may not fall out and its lenses become damaged.

2. Never allow the dry objective to touch the cover glass or the liquid in which the object is mounted.

3. Never touch the objective or ocular lenses with fingers or cloths.

4. Never change from lower to higher power objective without first ascertaining that the body tube has been raised sufficiently to allow the high-power objective to be slipped into place without injury to the objective or mounts.

5. Never clean the microscope lenses or stand with cloths that have been used for removing surplus of alkali, acid or other reagent from slides.

6. Note whether the front lens of the objective is clean before attempting to use it. If soiled, breathe on the lens and gently wipe with an old, clean, soft handkerchief or lens paper. If the lens be soiled with balsam or some other sticky substance, moisten the handkerchief or lens paper with a drop of xylol, taking care to wipe it perfectly dry as soon as possible.

7. Do not let the objective remain long near corrosive liquids, such as strong solutions of iodine, corrosive sublimate, or mineral

acids. Never examine objects lying in such fluids without putting on a cover glass.

8. Never lift the slide from the stage, but, after raising the objective, slide it off the stage without upward movement.

9. Never allow the *stand* (microscope without lenses) to be wetted with such substances as alcohol, soap, etc., which dissolve lacquer.

10. Keep the microscope covered when not in use.

MICROMETRY

The unit of length used in microscopic measurement is the *micron* (μ) which is one-thousandth part of a millimeter (0.001 mm.) or one twenty-five thousandth part of an inch.

FIG. 8.—Ocular micrometer.

In measuring microscopic objects it is necessary to make use of a micrometer of some kind. That pretty generally used is the *ocular micrometer* (Fig. 8). It is a circle of glass suitable for insertion within the ocular with a scale etched on its surface. The scale is divided to tenths of a millimeter (0.1 mm.) or the entire surface of the glass may be etched with squares (0.1 mm.), the net micrometer.

STANDARDIZATION OF OCULAR MICROMETER

The value of each division of the *ocular micrometer scale* must be ascertained for each optical combination (ocular, objective, and tube length) by the aid of a stage micrometer.

The *stage micrometer* (Fig. 9) is a slide with a scale engraved on it divided to hundredths of a millimeter (0.01 mm.), in some cases, also, to tenths of a millimeter (0.1 mm.), every tenth line being made longer than intervening ones, to facilitate counting.

METHOD:

1. Insert the ocular micrometer within the tube of the ocular by placing it on the diaphragm of the ocular, and adjust the stage micrometer by placing it on the stage of the microscope.

2. Focus the scale of the stage micrometer accurately so that the lines of the two micrometers will appear in the same plane. Make

the lines on the two micrometers parallel each other. This can often be done by turning the ocular to the right or left, while looking into the microscope.

3. Make two of the lines on the ocular micrometer coincide with two on the stage micrometer. Note the number of included divisions.

4. Note the known value for each division of the stage micrometer scale which may either be etched on the stage micrometer or indicated on a label found pasted upon it. If the value indicated is 0.01 mm. ($\frac{1}{100}$ mm.) then each division of the stage micrometer scale has a value of 10 microns; if 0.1 mm. ($\frac{1}{10}$ mm.), 100 microns.

FIG. 9.—Stage micrometer used to standardize the ocular micrometer. The mm. readings etched on this micrometer indicate the width of the larger and smaller spaces of the stage micrometer scale seen in the center of the stage micrometer.

5. Multiply the number of included divisions of the stage micrometer scale by the value in microns given for each division and divide the result by the number of included divisions of the ocular micrometer scale. The quotient represents the value of each division of the ocular micrometer scale.

6. Note the optical combination (number of ocular, objective and tube length) used and keep a record of it with the calculated micrometer value. Repeat for each of the combinations.

To measure an object by this method read off the number of divisions it occupies of the ocular micrometer scale, and express the result in microns by looking up the recorded value for the optical combination used.

CHAPTER IV

HISTOLOGICAL TECHNIQUE

In this chapter the various methods which are commonly employed in the preparation of plant materials for microscopic examination and the reagents used in the examination of the same will be discussed.

MAKING OF SECTIONS

Free-hand Sectioning. Free-hand sections are usually satisfactory for the general examination of roots, stems, leaves, barks and many fruits and seeds. Material which is fresh may be sectioned at once, but dry material should be well soaked in warm water before using. Fresh material should always be kept moistened in water on account of the danger of cell shrinkage through loss of water. Dried membranous or subleathery leaves should be kept in a moist chamber for at least 24 hours or until sufficiently supple before they are sectioned. Dried woody roots and stems can usually be best prepared for sectioning by soaking segments of these in equal parts of alcohol, glycerin and water for several weeks prior to using. Very hard material like heartwoods, the shells of nuts and seeds, may be softened in solution of caustic potash or ammonia water and then washed free of alkali before sectioning. Fine shavings can then be whittled off of these with a sharp knife. In some cases alternatingly boiling and cooling the material will suffice.

The object to be sectioned is held between the thumb and finger of the left hand. If tender and flexible, such as a fresh leaf, it must be placed between the two flat surfaces of elder pith before sectioning. A segment of pith about an inch long is halved lengthwise with a sharp knife and a portion of the leaf is held between the halves of pith while the section is cut through pith and leaf. The pith is later separated from the leaf section. Sections through other

delicate parts of plants, as buds, slender roots, etc., may be made in the same way, only a groove should be made in the pith of such size as is necessary to hold the material firmly enough without crushing it. In certain instances, when, because of the smallness of the object and its resistance to cutting, good sections can not readily be made with the aid of pith, a small sized cork stopper can be used with better results. A hole just large enough to prevent the object from slipping is made in the center of the smaller end and the object inserted preparatory to sectioning. The upper surface of the razor is wetted with 50 per cent. alcohol. The razor, which should be real sharp, is held in the right hand and is drawn across the object with the edge toward the student and the blade sliding on the fore-finger of the left hand. *The sections should be cut as thin as possible.* Small bits of representative parts of entire sections yield better results when examined under the microscope than complete sections which have been cut too thick. As soon as a number of sections have been cut, they can be transferred to a vessel of water with a camel's hair brush, before they become dry. If the sections are cut from fresh material and are to be stained, they should be placed in 95 per cent. alcohol for at least several minutes prior to staining. If from material preserved in formalin solutions, they should be washed in water.

Surface sections of leaves may occasionally be prepared by stripping off the leaf epidermis. In most instances, however, the leaf epidermis adheres firmly to the subjacent tissue and it becomes necessary to employ different technique. A good practice is to bend the leaf over the index finger of the left hand and hold it firmly between the index finger and the third finger on the one end and with the thumb on the other. Another method is the following: Place a representative portion of the leaf not over ¼ inch square in a watch crystal with 10 per cent. to 25 per cent. chloral hydrate solution, warm gently for several minutes, according to the texture of the leaf, transfer to a clean slide, add a drop or two of chloral hydrate solution, cover with cover slip and exert pressure on the cover slip with a rotary movement, describing the figure 8. The epidermis will thereby usually separate from the underlying tissues. It sometimes becomes necessary to study large areas of the epidermis of leathery

leaves. Such leaves should be prepared by boiling in 10 to 20 per cent. aqueous solution of either sodium or potassium hydroxide until the epidermis puckers up in the form of blisters when the epidermis can be lifted off by means of fine forceps or dissecting needles and floated on the slide.

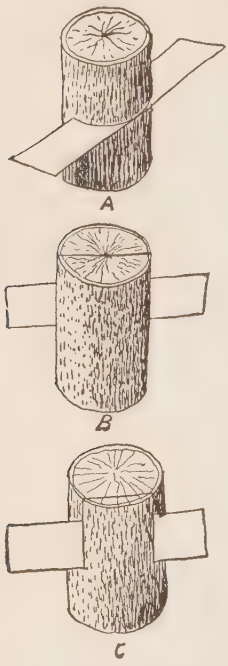

FIG. 10.—Showing the planes in which sections are cut, *A*, transversely; *B*, longitudinal radially; *C*, longitudinal tangentially. (*After Stevens.*)

Sectioning in Paraffine or Celloidin.—When it is necessary to study the microscopic structure of very delicate plant parts, superior results can generally be obtained by imbedding the material in paraffine or celloidin (see pp. 38 and 45), which is subsequently hardened, and sectioned by means of a sliding or rotary microtome.

KINDS OF SECTIONS

1. A *transverse* or *cross-section* is one made horizontally through the object, hence its plane lies at right angles to the long axis.

2. A *radial-longitudinal* section is one which is made parallel to the long axis of the object in such a way that it lies in the plane of the radius.

3. A *tangential-longitudinal* section is one made parallel to a plane tangent to the cylinder. This type of section is therefore prepared by cutting parallel to the outer long surface.

4. A *surface* section is one made by cutting or stripping off the outer protective covering of the plant organ.

MICROTOMES

Microtomes are instruments employed to facilitate the cutting of sections of organic tissues. The three most commonly used types are the hand, sliding and rotary microtomes.

Hand Microtome.—This type is shown in Fig. 11. If the object is sufficiently hard to bear the strain, it is placed directly in a clamp

at the upper end of the tube that is tightened by the screw seen on the side of the tube, or it may first be inclosed in elder pith or cork and then clamped in. The object to be sectioned is raised a little at a time through the hole in the glass plate at the top by turning the finely graduated feed near the base of the tube. The section razor is then laid flat on the glass plate and pulled across the object with a long sliding motion. The upper surface of the razor blade is kept wet with 50 per cent. alcohol and after several sections have been cut they can be swept by the finger or camel's hair pencil to a dish of water. Each division of the feed represents 10 microns, so that the thickness of sections desired can be regulated by moving the feed, accordingly, just before each stroke of the razor.

FIG. 11.—Hand microtome. Description in text.

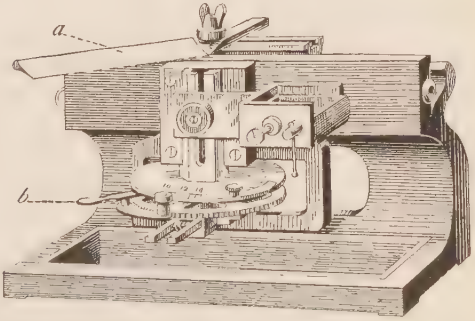

FIG. 12.—A sliding microtome. Blade (*a*); lever (*b*). (*From McJunkin.*)

Sliding Microtome.—This type of microtome (see Fig. 12) is adapted for cutting all kinds of sections. It consists of an iron supporting frame of horizontal and upright portions. The horizontal base rests on the table and is hollowed out to accommodate a drip pan that can readily be removed and cleaned.

The front of the upright portion exhibits a frame which accommodates a sliding feed mechanism to which is attached the object carrier. The top of the upright portion shows a V-shaped bed which carries a solid iron block which can be readily slid along the bed when

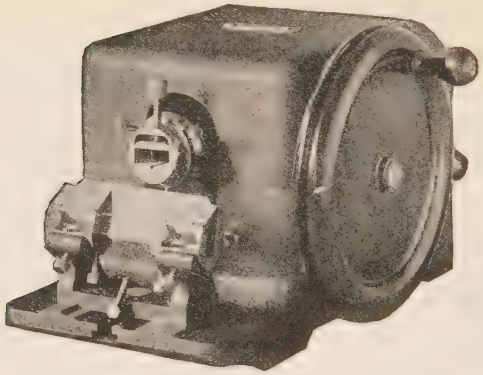

FIG. 13.—Rotary microtome. The feed mechanism is covered to protect the wearing parts from dust.

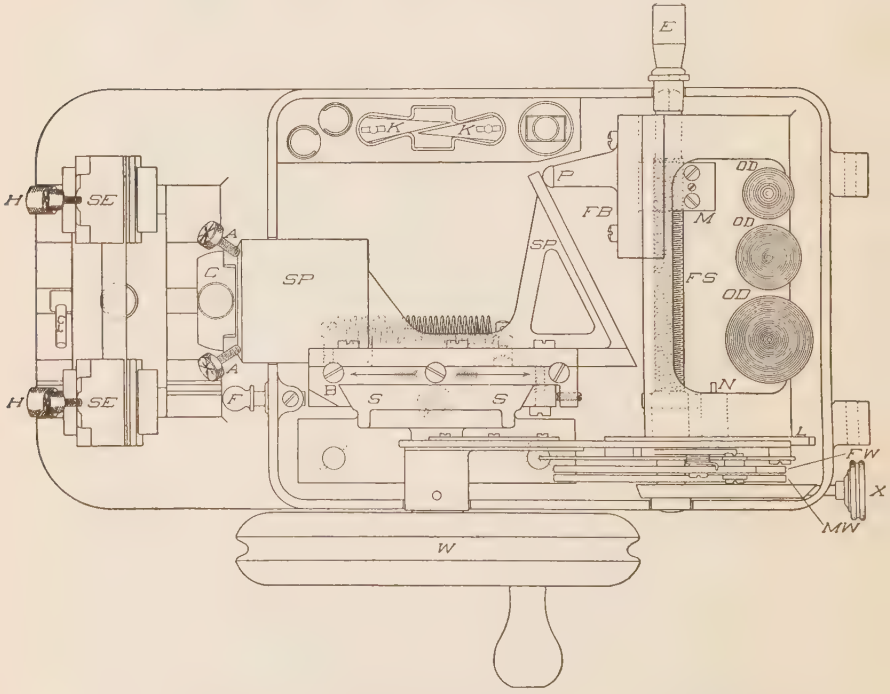

FIG. 14.—Plan of construction of rotary microtome shown in Fig. 13.

the latter is lubricated with paraffin oil. The upper surface of the block is grooved to accommodate the thumb screw. The microtome knife consists of a blade portion (*a*) that is flat on its lower and hollow ground on its upper face, and a forked handle. The latter is slid into the stem of the thumb screw which has previously been slid into the groove of the block and its position adjusted. Sections of woody material can be cut directly on this microtome and placed in dilute alcohol. When paraffine sections are cut, the cutting edge of the knife should be parallel to the motion; but when celloidin sections are desired the knife must be set at an oblique angle to the frame and drawn across the block with a long sliding motion. The knife and the top of the celloidin block must be constantly kept wet with 80 per cent. alcohol.

The object is placed in the object carrier and clamped in. By means of the graduated disk at the base of the feed mechanism the thickness, in terms of microns, is regulated after each stroke of the razor.

Rotary Microtome.—When paraffin ribbons are desired, especially for the study of serial sections of material, the rotary microtome surpasses by far the efficiency of the sliding type of instrument. The Spencer Rotary Microtome No. 820 is shown in Fig. 13 and its plan of construction illustrated in Fig. 14. In this instrument the sliding part which carries the object clamp (SP) is carried up and down by the block (B). The feed mechanism consists of a rigid bearing, on which the feed block (FB) (of which the projection P is a part), is moved by the feed screw (FS). As this block travels toward the side on which the balance wheel (W) is located, the sliding part (SP) is forced forward towards the knife one-half as much. The polished surface set against the point (P) is arranged at the proper angle to accomplish this end. The screw, cut with two threads to the millimeter, is revolved by a ratchet feed wheel with 250 teeth. Each tooth represents a forward movement of the object of one micron. The feed can be set for sections from 1 micron to 60 microns thick, by turning the button at the back of the case until the number, representing the desired thickness, appears opposite the indicator at the small opening in the side of the case near the balance wheel. The total excursion of the feed is 37 mm. This allows a sufficient range for cutting a com-

plete series of sections of a large object without the necessity of a break due to resetting the knife and feed mechanism. The object, after being placed in the object clamp, may be oriented to any desired angle. The clamp is held at its upper limit for orienting or trimming the block by pushing in the pin (F). The whole knife support may readily be adjusted to and from the object, and is readily clamped in any location by a lever connected with an eccentric cam. The knife is fastened by two clamps and may be turned to any desired angle. The clamps can also be moved toward each other to bring them as near to the ribbon as desired to gain additional rigidity. The groove in the balance wheel is designed for a cord or strap, when it is desired to run the instrument by a motor.

REAGENTS AND STAINS

The following reagents will be found of value in the microscopical examination of plants, powdered vegetable drugs and foods: (additional reagents and formulas for their preparation are presented elsewhere in the text in connection with methods of examination).

Acetic Acid.—This reagent should contain not less than 36 per cent. nor more than 37 per cent. of pure acetic acid. It is used for various operations such as distinguishing between calcium carbonate which dissolves in it with effervescence and calcium oxalate which is insoluble in it. A 2 to 3 per cent. solution is occasionally employed as a mounting medium for microscopic plants.

Acid Alcohol.—Mix $\frac{1}{10}$ cc. hydrochloric acid with 100 cc. of 70 per cent. alcohol. This is employed in removing the excess of stain from overstained material. When used, it should be thoroughly washed out with diluted alcohol or water.

Alcohol.—Useful in the form of various percentage solutions for dehydrating, preserving, hardening and solvent purposes. Absolute alcohol should contain not less than 99 per cent. by weight of ethyl hydroxide and must be kept in well stoppered bottles because of its property of rapidly absorbing moisture from the air and so becoming reduced in strength. It should always be used before cedar oil or xylol in making a balsam mount, but if clove oil is used for clearing instead of cedar oil or xylol, 95 per cent. alcohol may be employed.

Alcanna Tincture.—Macerate 20 Gm. of alkanet root for a week in 100 cc. of 90 per cent. alcohol, boil for several minutes and cool. Dilute with an equal volume of water just before using. This reagent imparts a red color to fixed oils but may stain other contents as well.

Ammonia Water.—An aqueous solution of gaseous ammonia containing not less than 9.5 per cent. nor more than 10.5 per cent. by weight of NH_3. Useful in clearing highly colored vegetable powders, such as ground roasted coffee, when mixed with equal parts of peroxide of hydrogen. Material should be macerated in this mixture within a tightly corked vial over night or longer and washed with water before examination.

Ammonia Water, Stronger.—This is an aqueous solution of NH_3 containing not less than 27 per cent. nor more than 29 per cent. by weight of ammonia gas. It is employed in the preparation of cuoxam.

Aniline Chloride.—A saturated aqueous solution acidified with hydrochloric acid is useful in staining lignified walls which are colored a golden yellow.

Aniline Sulphate.—A saturated aqueous solution is employed as a test for lignified walls. Sections are mounted in this reagent and a drop of sulphuric acid added. A yellow color is imparted to lignified walls.

Aniline Blue.—A saturated aqueous solution is useful in staining sieve tubes. Sections should be placed in this solution for 24 hours and then washed to remove excess of stain. A one per cent. solution in 90 per cent. alcohol is used in double-staining with safranin. It stains cellulose walls blue.

Bismark Brown (Aniline Brown).—A saturated aqueous solution is useful in double staining with gentian violet. A dilute aqueous solution is of value in staining transparent tissues.

Chloral Hydrate.—A solution prepared by dissolving 25 Gm. in 10 cc. of water is an excellent clearing agent. It dissolves starch, resin, protein, chlorophyll, etc., and causes more or less expansion of shrunken cells.

Chloral Iodine.—Saturate the previously prepared chloral hydrate solution with iodine by adding crystals of resublimed iodine to it and

shaking. Useful for the detection of minute traces of starch or small starch grains, which are colored blue.

Chlorzinciodine Solution.—Dissolve 25 Gm. of anhydrous zinc chloride and 8 Gm. of potassium iodide in 8.5 Gm. of water and add iodine crystals to saturation. Keep in dark colored containers. Useful in distinguishing between cellulose and lignified walls. Cellulose walls are colored blue or violet and lignified walls yellow when mounted in this solution. It causes starch grains to swell and colors them blue.

Chromic Acid Solution.—Dissolve 5 Gm. of chromic acid in 45 cc. of diluted sulphuric acid (U.S.P.). A valuable reagent for separating the component cells in sections of plant organs. The sections are placed in this solution in a watch-glass and removed one by one, as required, in the course of 10 to 15 minutes to a slide, washed with a few drops of water and subjected to pressure with a glass rod.

Corallin Soda Solution.—Dissolve 15 Gm. of carbonate of soda in 35 Gm. of distilled water and add sufficient corallin to produce a pale bright pink color. This reagent stains the callus plates of sieve tubes pink. It should be freshly prepared as needed.

Cuoxam.—This is a valuable reagent for dissolving cellulose. It should be prepared freshly when required, since it gradually loses in strength. Triturate 5 Gm. of copper carbonate with 100 cc. distilled water, add 100 cc. of stronger ammonia water and place solution in a well stoppered bottle.

Eosin.—An aqueous solution is useful in the staining of cytoplasm, aleurone grains and other cell contents. If permanent mounts are desired, transfer to 1 per cent. acetic acid for a minute, wash with water, then to glycerin or through glycerin to glycerin jelly.

A saturated alcoholic solution of eosin (using absolute alcohol as solvent) is employed when eosin-stained material is to be mounted in balsam. Acetic acid is omitted in this case and the sections passed from alcoholic eosin to a clearing agent as cedar oil or xylol, thence into balsam.

Ether.—Useful in defatting sections or powders of oily seeds.

Fehling's Solution.

Copper Solution.—Dissolve 34.66 Gm. of small, uneffloresced crystals of cupric sulphate in sufficient distilled water to make the mixture measure 500 cc. Keep in well stoppered bottles.

Alkaline Tartrate Solution.—Dissolve 173 Gm. of crystallized potassium and sodium tartrate and 50 Gm. of sodium hydroxide in sufficient distilled water to make the solution measure 500 cc. Keep in rubber-stoppered bottles.

Mix exactly equal volumes of the two solutions when required. This solution yields a precipitate of cuprous oxide with reducing sugars.

Ferric Chloride Solution.—A 1 per cent. solution of ferric chloride in distilled water is used to detect the presence of tannin. It yields a dark green to bluish-black precipitate with tannin.

Fuchsin (Basic).—Dissolve 1 Gm. of fuchsin in 100 cc. of 95 per cent. alcohol and add an equal volume of water. This solution will impart different tints of red to the various tissues. It has been found especially useful in staining sections which are to be photomicrographed.

Fuchsin, Acid.—A 0.2 per cent. aqueous solution is useful in staining plastids and the phytoglobulins of aleurone grains. A 1 per cent. solution in 50 per cent. or 70 per cent. alcohol is occasionally employed in conjunction with methyl green in the double staining of tissues of plants.

Gentian Violet.—An aqueous solution, made by dissolving sufficient of the dye in 1 per cent. acetic acid solution to impart a deep violet color, is useful in fixing and staining pollen grains, spores and other fresh plant material. A 1 per cent. solution in distilled water is used in conjunction with Safranin and Orange G. solutions in staining material used for the study of nuclear divisions.

Glycerin, Dilute.—Equal parts of pure glycerin and distilled water. Used as a mounting medium.

Glycerine Gum.—Dissolve 20 Gm. of gum arabic and 20 Gm. of glycerine in 15 cc. of water. Useful for fixing small fruits or seeds on pith before sectioning.

Hæmatoxylin, Delafield's.—Used for double-staining, see p. 45.

Hydrochloric Acid.—The concentrated C.P. acid is used with an equal volume of Phloroglucin Solution in determining lignification. Dilute solutions are employed for neutralizing alkaline solutions, etc.

Iodine Water.—Add as much iodine to distilled water as it will dissolve. Stains starch pale blue to purplish-blue.

Iodine and Potassium Iodide Solution.—Dissolve 1 Gm. of iodine and 3 Gm. of potassium iodide in 50 cc. of water. Keep in glass stoppered bottles. This reagent stains cellulose, lignified and corky walls and proteins yellow and starch blue to bluish-black.

Labarraque's Solution.—Triturate 50 Gm. of fresh chlorinated lime with 250 cc. of water so as to form a uniform mixture. Dissolve 35 Gm. of monohydrated sodium carbonate in 250 cc. of hot water, and add this solution to the chlorinated lime mixture in a suitable vessel. Stir or shake thoroughly. (Warm if solution gelatinizes.) Transfer the mixture to a wetted muslin strainer, returning the first portion until the liquid passes through clear, and when no more liquid drains from it, wash the precipitate with sufficient water to make the product weigh 500 Gm. Keep in amber colored, glass stoppered bottles in cool place. It gradually loses in strength on standing. This reagent is used for bleaching highly colored sections and powders. The materials bleached should always be washed with water before mounting.

Light Green.—This is used as a combination stain with safranin. Dissolve 1 Gm. of light green in 100 cc. of clove oil; 25 cc. of absolute alcohol and 75 cc. of clove oil may be used in place of the pure clove oil, if the light green is found to precipitate out when xylol is subsequently employed as a clearing agent.

Naphthol Solution.—Dissolve 5 Gm. of alpha-naphthol in 50 cc. of alcohol. Used in conjunction with concentrated sulphuric acid for the detection of inulin. A violet coloration is produced if sections containing inulin are first treated with a drop or two of this reagent and then, after a minute, a drop on two of sulphuric acid be added.

Petroleum Ether.—Useful in clearing sections or powdered material of oil.

Phloroglucin Solution.—Dissolve 1 Gm. of phloroglucin in 50 cc. of 95 per cent. alcohol. This solution gradually darkens and loses strength with age. It is unfit for use after three or four months. The lignified walls of elements first treated with several drops of this solution and subsequently with a drop or two of concentrated hydrochloric acid are colored red.

Potash Solution.—Several percentage solutions are employed in histological technique for varying purposes. The most commonly

used one in the 5 per cent. aqueous solution which is used for clearing sections of starch, protein and tannin. Ten to 20 per cent. aqueous solutions are used for the purpose of separating the epidermis of leathery leaves. The leaf material is boiled in the strong potash solution until the epidermis puckers up in the form of blisters, when it should be removed to a slide and the epidermis lifted off by means of a fine forceps or dissecting-needles. *A 2 per cent. solution is used for the isolation of laticiferous vessels from plant organs.* Pieces of stems, barks or roots containing these elements are placed in a test tube and digested on a water-bath for a half hour or longer until the parenchymatous tissues are sufficiently soft. The potash solution is then poured off and the material washed with water, transferred to a slide and the woody or other undesirable parts removed with the aid of dissecting needles. The softer parts are then stained with iodine and potassium iodide solution; a cover slip is adjusted, the slide placed on stage, and the laticiferous tissues are identified by the presence of branching and anastomosing tubes stained yellow to yellowish-brown with granular contents.

Ruthenium Red and Lead Acetate Solution.—This is an excellent reagent for the detection of mucilage, to which it imparts *a pink color.* Add sufficient ruthenium red to a 10 per cent. solution of lead acetate until it shows a wine-red color. The lead acetate solution should be prepared with distilled water and the ruthenium red added to quantities of it as needed, as the reagent is unstable. In pharmacognosy, it is especially useful in detecting powdered cacao shells in powdered cocoa and chocolate, since the cacao shells are the only portions of the cacao seed which contain mucilage.

Safranin.—Several kinds of safranin solutions are in use, viz., Alcoholic Safranin, Anilin Safranin and Aqueous Safranin. *Alcoholic Safranin* is prepared by making a saturated solution of safranin (alcohol soluble) in 95 per cent. alcohol and then adding an equal volume of water. *Anilin Safranin* is made by mixing equal parts of saturated alcoholic solution of safranin with aniline water. *Aqueous Safranin* represents a 1 per cent. solution of safranin (water-soluble) in water. Safranin solutions stain both protoplasmic contents and cell walls red.

Sulphuric Acid.—Concentrated sulphuric acid, containing from 93 to 95 per cent. of H_2SO_4 is useful in the detection of suberized or corky walls. These resist its action, while lignified and cellulose walls are completely dissolved by it. This acid as well as dilutions of it with water are also employed *per se* or with various chemicals in a number of microchemic tests.

Additional reagents and stains are discussed under appropriate headings in this and other chapters of the text.

THE TECHNIQUE OF MAKING A TEMPORARY MOUNT

1. Place a drop or two of water (or reagent) in the center of a clean glass slide.

2. With the aid of a forceps take the section or very small quantity of the material to be examined and spread it on the drop of water.

3. Place a clean cover-glass over the material. In placing the cover-glass, do not drop it flat upon the drop of water, but place one side of it down first and allow it to squeeze the water along under it.

4. Keep the top of the cover-glass dry.

When filamentous algæ or molds are to be examined, the material tends to cling together and must be carefully separated, in the drop of water, with dissection needles before the cover-glass is placed over the material. In case a coarse ground drug is to be mounted, the coarser particles should be first crushed in the water on the slide and subsequently teased apart with dissection needles.

Care should always be taken to see that the water or mounting medium used is not contaminated with foreign substances. This can best be practiced by examining the mounting medium under the microscope before the material to be examined is placed in it.

THE TECHNIQUE OF MAKING PERMANENT MOUNTS

1. **The Mounting Medium.**—When a microscopic object is to be preserved permanently it must be kept from decaying and the fluid in which it is placed must be kept from evaporating. These conditions can be met by adding an antiseptic (2 per cent. acetic acid, or formaldehyde) to the water used in mounting and carefully sealing the cover glass with asphaltum or zinc white. As a rule, a better way is to use a mounting medium that will not evaporate, *e.g.*,

glycerine, glycerin gelatin or Canada balsam. These fluids have a high refractive index and so render the objects penetrated by them more transparent. This quality is generally an advantage, but for objects already almost transparent it is quite the reverse. Glycerine has the disadvantage of always remaining soft, so that the mount may at any time be spoiled by careless handling. Glycerin-gelatin has the advantage of mixing readily with 50 per cent. glycerin in which the object should be placed before being mounted in this medium. It should be warmed on a water bath before using and the cover-glass applied quickly after it is placed on the specimen. It cools rapidly and constitutes the quickest and simplest means of effecting a durable permanent mount. Its disadvantage is due mainly to its jelly like consistency which is frequently responsible for damaged mounts when the cover-glass above the preparation is too greatly strained. Canada balsam slowly becomes solid, so that the mount is exposed to no accident short of actual breakage. Balsam has the disadvantage of being non-miscible with water, so that before it can be used the object must be carefully dehydrated. Even after this is done, and the object lying in absolute alcohol, a clearing oil such as cedar oil, clove oil or xylol must be used as an intermediate agent between alcohol and balsam.

2. **Staining.**—For two reasons it is generally better to stain plant tissues before mounting. Transparent tissues may become almost invisible in glycerine, glycerin-gelatin, or balsam, and different tissues take a stain differently. This being the case it becomes possible to stain one tissue and not another, or one tissue with one stain and another in the same section with a different stain (*double staining*), so that the different parts may be brought out like areas on a colored map. The most common stains are hæmatoxylin derived from logwood, and various anilin stains—safranin, fuchsin, eosin, light green, iodine green, methyl-green, malachite green, etc.

METHODS FOR THE PREPARATION OF CANADA BALSAM MOUNTS

No. 1. Safranin and Light Green

1. Stain object with either alcoholic safranin or anilin safranin (1 per cent. solution in 50 per cent. alcohol) for 2 to 24 hours or by gently warming object in the safranin solution until vapors arise.

2. Wash out excess of stain with 50 per cent. alcohol.

3. Dehydrate with 95 per cent. alcohol for two minutes.

4. Further dehydrate by placing material in absolute alcohol for 20 to 30 seconds.

5. Stain with a saturated solution of light green in clove oil for from 3 to 30 minutes.

6. Clear in xylol for 1 minute. Blot up excess from around edge of section.

7. Mount in Canada balsam.

8. Label slide.

The safranin will impart a red color to the suberized and lignified walls, while the light green will stain cellulose walls green.

Should the light green precipitate upon clearing in the xylol, add 3 cc. of absolute alcohol to each 100 cc. of xylol.

Should air-bubbles be detected in the balsam shortly after mounting, heat a dissection needle in a flame and touch each with its tip, when they will be found to disappear.

If too much Canada balsam has been used, some of it usually spreads beyond the edge of the cover-glass, or on its surface. In this event wait until the balsam hardens, when it can be scratched off with a knife, and the surface of the glass cleaned with a rag moistened with turpentine oil or xylol.

Should the Canada balsam become too thick, it can be thinned down with either xylol or benzol.

No. 2. Safranin and Anilin Blue

1. Stain sections with either alcoholic or anilin safranin (1 per cent. sol. in 50 per cent. alcohol) for from 2 to 24 hours or by heating them in the staining fluid until vapors arise.

2. Wash out excess of stain with 50 per cent. alcohol. Be careful not to remove too much of the safranin. Washing should stop as soon as the stain is reduced to a pink in cellulose walls.

3. Stain with Aniline Blue (1 per cent. sol. in 90 per cent. alcohol) for from 3 to 10 minutes.

4. Wash in 95 per cent. alcohol for a few seconds.

5. Rinse with slightly acidulated 95 per cent. alcohol for a few seconds.

6. Wash for 1 to 2 minutes in 95 per cent. alcohol containing a trace of an alkali to remove the acid.

7. Dehydrate with absolute alcohol for two minutes.

8. Clear in cedar oil for one minute. Blot up excess of cedar oil from around section. Clove oil or xylol may be substituted for the cedar oil.

9. Mount in balsam.

10. Label slide.

If the sections are properly stained, the lignified and suberized walls will be stained red and the cellulose walls a brilliant blue.

No. 3. Safranin and Methyl Green

1. Stain sections with either alcoholic safranin or anilin safranin for from 2 to 24 hours or by warming them in the safranin solution until vapors arise.

2. Remove excess of stain by moving sections about in a vessel of 50 per cent. alcohol until the cellulose walls are pink in color.

3. Stain with 0.5 to 1 per cent. solution of methyl green for from 30 seconds to 5 or 10 minutes. Good results with this stain requires experience with the materials to be stained. The average hand cut section requires 10 minutes.

4. Remove excess of stain and dehydrate in 70 per cent. alcohol for several seconds.

5. Dehydrate with 95 per cent. alcohol for 10 seconds.

6. Further dehydrate by placing material in absolute alcohol for one minute.

7. Clear in cedar oil for one minute. Blot up excess of oil from around edge of section.

8. Mount in Canada balsam.

9. Label slide.

If the sections are properly stained, the lignified and suberized walls will be stained red and the cellulose walls green.

METHOD FOR THE PREPARATION OF A GLYCERIN-GELATIN MOUNT

1. Stain object with an aqueous solution of eosin.

2. Transfer to 1 per cent. acetic acid for a minute.

3. Wash out acid and excess of stain by moving the section about in a dish of water.

4. Transfer object to weak glycerin (glycerin 10 parts, water 90 parts) for 3 to 5 minutes.

5. Transfer object to 50 per cent. glycerin for 3 to 5 minutes.

6. Transfer object to concentrated glycerin for 5 minutes.

7. Remove excess of glycerin around object and mount in glycerin-gelatin. The slide and cover slip should be warmed before the glycerin-gelatin is dropped over the object and the cover slip quickly lowered. The preparation of Glycerin-Gelatin is as follows: Macerate 14 grams of gelatin in 84 cc. of water for 2 hours, add 76 cc. of glycerin and warm; add 2 cc. of liquefied phenol, warm and stir for 15 minutes until clear. Filter while hot through glass-wool or filter paper and collect the filtrate in a wide mouthed bottle. Keep well stoppered so as to exclude dust.

Glycerin-gelatin becomes solid when cool. For use warm the bottle in a water bath after first removing the stopper. A glass rod sufficiently long to reach to the bottom of the bottle can be inserted in the cork and used for transferring the material to the slide.

8. Ring mount with zinc white, balsam or asphaltum at the edge of cover slip. If the cover slip is circular, this can best be done by means of a centering turn-table. A camel's hair brush is dipped into the zinc white, balsam or asphaltum and held to the margin of the cover slip while the slide fastened with clips to the turn table, is rotated with it.

9. Label slide.

If the objects or sections are such as not to be liable to shrink they can be transferred from water or weak glycerin directly to glycerin-gelatin.

TECHNIQUE OF FIXING, DEHYDRATING, HARDENING AND IMBEDDING IN PARAFFIN

When the intention is to study the protoplasts in their natural form or the processes of cell division, the fresh material must be put through the various stages of fixation, hardening and imbedding before it is sectioned. The steps will now be considered in the order in which they must be carried out.

Fixation.—This is the process of killing and coagulating the protoplast. The essence of good fixation is in rapid killing. It should be simultaneous with coagulation or hardening so that the protoplast will not be modified by later treatment. Fixing fluids are always substances unknown to protoplasm, *e.g.* poisons. The coagulation of protoplasmic structures is due to the fact that these are alkaline in reaction whereas the fixing fluid is acid. Fixing fluids must be judged not only as to killing and hardening but also as to reaction of tissues to stains afterward. Fluids that are mixtures make the best fixing agents. Among the fixing agents employed are the following: Osmic acid (OsO_4) comes in sealed glass tubes containing 0.5 gm. or 1 gm. It has a very powerful odor and is easily affected by organic materials. It is used in 1 to 2 per cent. solutions and should be made up in distilled water. It fixes cytoplasm well but the nucleus not as good. Its disadvantage lies in its inability to penetrate rapidly.

Chromic acid (CrO_3) in 0.5 to 1 per cent. aqueous solution is very favorable for nuclear structure but like osmic acid penetrates rather slowly.

Picric acid $C_6H_2(OH)(NO_2)_3$ is one of the most penetrating fixing fluids but has very little hardening power. It is employed in saturated aqueous solution.

Corrosive sublimate ($HgCl_2$) in 0.2 per cent. aqueous or alcoholic solution penetrates and hardens rapidly but does not give as sharp optical differentiation as the others considered.

Absolute alcohol can be employed for very small objects that are dry. If the objects are moist shrinkage will follow.

Carnoy fluid, consisting of 6 parts absolute alcohol, 3 parts formaldehyde and 1 part of glacial acetic acid, can also be used for fixing small objects. It has the advantage of fixing these in about 10 minutes. Moreover the objects can be carried directly to absolute alcohol, thence to hot melted paraffin and imbedded.

Formalin-alcohol, consisting of from 2 to 6 per cent. of formalin in 50 to 70 per cent. alcohol is a good fixing and preserving agent for materials which are not of very delicate texture. It should not be used for unicellular or filamentous algæ and fungi. For these 2 to 6 per cent. aqueous solutions of formalin have given good results.

Material can be left in the formalin solutions until required for use, provided care be exercised in storing it in air-tight containers.

For most materials the Flemming fluids have proven very satisfactory and are the most generally employed. They are of two classes, viz.; 1. Those that simply involve chromic acid and acetic acid (the chrome-acetic fluids) and 2. Those that involve chromic acid, acetic acid and osmic acid (the Chrome-Osmium-Acetic Fluids). The formulæ follow:

CHROME-ACETIC FLUIDS

Strong	1 per cent. Chromic acid solution	100 cc.
	Glacial acetic acid	1 cc.
Medium	1 per cent. Chromic acid solution	70 cc.
	1 per cent. Glacial acetic acid	1 cc.
	Distilled water	29 cc.
Weak	1 per cent. Chromic acid solution	25 cc.
	1 per cent. Glacial acetic acid	10 cc.
	Distilled water	65 cc.

CHROME-OSMIUM-ACETIC FLUIDS

Strong	1 per cent. Chromic acid solution	75 cc.
	2 per cent. Osmic acid solution	20 cc.
	Glacial acetic acid	5 cc.
Weak	1 per cent. Chromic acid solution	25 cc.
	1 per cent. Osmic acid solution	10 cc.
	1 per cent. Acetic acid solution	10 cc.
	Distilled water	55 cc.

The acetic acid in all of the Flemming fluids is of great advantage since it penetrates very rapidly, carrying the chromic acid or chromic and osmic acids into the tissue depths, thus insuring complete fixation.

The material to be fixed should be cut into small pieces not longer than 5 mm. nor broader than 2 or 3 mm. The amount of fixative to be used should not be less than 15 times the bulk of the material to be fixed. For delicate material, the weak fixing fluid is used, while for the slightly woody the medium strength fluid and for the

more woody, the strong fluid is indicated. The material should be placed in the fixing fluid immediately after it is gathered. One or two drachm homepathic phials are convenient for the process. The material is kept in the fixing fluid for from 12 to 24 hours and then washed in small cheese cloth bags which are placed in running tap water for from 6 to 12 hours or over night.

Dehydrating and Hardening.—After washing, the material, still kept in the bags, is placed in 10 per cent. alcohol for 1 hour and is then carried through a series of alcohols. Each of the series 10 per cent. stronger than the one before it, remaining in each grade for 1½ to 2 hours until 70 per cent. alcohol is reached. Take out of bag and place in phial in 70 per cent. alcohol. If the material is not to be imbedded in paraffine immediately, it can remain in 70 per cent. or 85 per cent. alcohol (if very delicate) until needed. It is not safe to leave very valuable material in a grade below 70 per cent. over night. From the 70 per cent. alcohol it is carried to 85 per cent. to 95 per cent. to absolute alcohol, remaining in each at least 6 hours with 2 or 3 changes of the last.

Clearing and Imbedding.—In order to get the material from absolute alcohol into paraffine, some medium must be used which mixes with absolute alcohol and which also dissolves paraffine. Either oils such as cedar, clove or bergamot or substances like xylol, chloroform or benzol satisfy this requirement. To clear with xylol —transfer material from absolute alcohol to a mixture of ¾ absolute alcohol and ¼ xylol for 12 hours, then to mixture of equal parts of absolute alcohol and xylol for 12 hours, then to ¾ xylol and ¼ absolute alcohol for 12 hours to pure xylol for 12 hours. To phial containing material in pure xylol add paraffine in small pieces and put on top of paraffine bath sufficiently long until paraffine is melted. Then add more paraffine and put phial in paraffine bath at 56°C. over night. Pour fluid off and add pure melted paraffine and repeat 2 or 3 times until rid of all trace of xylol. A tray is then prepared by taking a piece of paper and folding up its edges all around to the height of about a half inch. Half fill this on a cool surface with melted paraffine. Heat two dissection needles in bunsen flame and with these dispose pieces of material in orderly fashion over the crust which has by this time formed at the bottom of the tray.

Blow upon the surface of the paraffine to harden it more quickly and as soon as the surface crust will bear it, plunge the tray into cold water. The material can now be left imbedded in paraffine until required for sectioning.

If cutting is to be done in a cool room, softer grades of paraffine with melting points between 40° and 50°C. should be used for imbedding. If, on the other hand, cutting is to be done at summer temperatures, the harder grades melting at between 55° and 70°C. should be employed.

TECHNIQUE OF SECTIONING AND MOUNTING MATERIAL IMBEDDED IN PARAFFINE

Strip off the paper tray from the imbedded material and cut out a block of paraffine containing the object which is to be sectioned, taking care to include at least 2 or 3 mm. of paraffine on all sides beyond the specimen. Take a segment of pine wood about an inch long and with a surface at one end about $\frac{3}{8}$ in. square, and coat the square area with melted paraffine. Warm the paraffine on the piece of pine wood and quickly press the paraffine block containing the specimen into this melted paraffine in the desired position for cutting. Heat a dissecting needle and apply this all around the base so that the paraffine block is firmly sealed to the wood. Dip paraffine block in cold water to harden. Now trim the paraffine block with a sharp scalpel so that the faces form right angles with each other. Adjust the wood in the clamp of the microtome and the microtome blade so that the top of the paraffine block just touches the near surface of the microtome knife. Make certain that the knife edge and the two opposite faces of the paraffine block are perfectly parallel. Now trim the remaining two sides of the block close to the object. Adjust the automatic feed of the rotary microtome by moving dial to number on scale representing thickness in microns desired of sections and turn wheel of microtome. It will be observed that the carrier moves up and down and with each downward movement slightly forward, causing the knife to cut sections which adhere in ribbons.

Transfer the ribbons by means of a camel's hair pencil or dissecting needle to a piece of dust free paper with the side downward which was

next to the knife. The ribbons are now ready to be mounted on slides.

The slides to be used should only be those which are devoid of grease or dirt of any kind particularly on the surface upon which the ribbons are to be mounted. A very good plan is to keep a number of slides intended for this purpose submerged in a saturated solution of potassium dichromate in concentrated sulphuric acid. These can be taken out as needed and thoroughly rinsed with water.

With a clean cloth stretched over the forefinger vigorously rub one surface of each slide until perfectly dry and free of lint. Then place a small drop of Mayer's albumin fixative on clean surface and rub over the surface. (The formula for Mayer's Albumin Fixative is as follows: Egg white and Glycerin, equal parts, Salicylate of Soda, 1 Gm. to each 100 cc. Mix thoroughly and filter.) Now flood the surface with water and cut the ribbons into segments of the desired length and arrange in rows on slide, being careful to have the segments somewhat shorter than the length of the cover slip because of tendency of paraffine to stretch when warmed. Warm slide gently by holding high above a bunsen flame or flame of an alcohol lamp until ribbons stretch out in smooth fashion. Absorb superfluous water from beneath ribbons with blotting paper held to their edges and at same time push the sections into even rows. Then leave the sections to dry for several hours or over night.

METHOD FOR THE STAINING AND MOUNTING OF MATERIAL IN PARAFFINE RIBBONS AFFIXED TO SLIDE

1. Gently heat the dry slides with paraffine ribbons adhering to the fixative, high above the Bunsen flame (with the ribbon side up).

2. Place the slide upright in a well of xylol or turpentine. The xylol or turpentine will dissolve the melted paraffine in a minute or two.

3. Take the slide out of the well, wipe off the under side and allow a stream of 95 per cent. alcohol to run over the upper side from a pipette.

4. Place the slide upright in a well of safranin for from four to twenty-four hours

5. Take the slide out of the safranin well and extract excess of stain with 50 per cent. alcohol. If impossible to extract excess of

safranin by this procedure, use acid alcohol and remove acid by washing with 50 per cent alcohol.

6. Place the slide in a well of gentian violet or methyl-green for a second or more. The time varies for different objects and can only be determined by trial.

7. Rinse slide with 70 per cent. alcohol from pipette.

8. Pour absolute alcohol over sections, follow with a few drops of clove oil, replace clove oil with cedar oil.

9. Mount in balsam.

10. Label slide.

IMBEDDING IN CELLOIDIN

Whenever material is unsuited for free hand sectioning and will not give good results when imbedded in paraffine on account of size, hardness, or brittleness, celloidin may be resorted to as an imbedding medium.

The technique employed is similar to that of the paraffine method so far as the preliminary fixing, hardening and dehydrating are concerned up to and including the 95 per cent. alcohol stage. From this point the various succeeding steps in the procedure are as follows:

1. Place material in equal parts of 95 per cent. alcohol and ether (known as ether-alcohol) for several hours.

2. Transfer to a 2 per cent. solution of celloidin in ether-alcohol, for 2–5 days.

3. Transfer to a 6 per cent. solution of celloidin in ether-alcohol, for 2–5 days.

4. Transfer to a 12 per cent. solution of celloidin in ether-alcohol, for 3–10 days.

5. Prepare a pine block sufficiently large in cross section to support the material and otherwise adapted to its being clamped in the object carrier of the microtome. Soak one end of this block in ether-alcohol for a while and then dip it in the 2 per cent. celloidin solution.

6. Take the material from the thick celloidin and set it in proper position, for cutting the sections desired, on the prepared end of the block and allow the celloidin to thicken for a few seconds only.

7. Dip the celloidin end into the thick solution; remove and hold upright so that the new coating may spread out over the end of the block and solidify the union.

8. As soon as the celloidin has hardened a little to form a surface film, drop the preparation into a vessel of chloroform and allow to remain here 1 day.

9. Transfer preparation to a vessel containing equal parts of glycerin and 95 per cent. alcohol until required for sectioning.

SECTIONING CELLOIDIN MATERIAL

Clamp the block in the sliding microtome and set the knife obliquely so that the sections can be cut with a long sliding stroke. Keep the knife and top of the block wet with the alcohol-glycerin mixture and as soon as the sections are cut, sweep them with a camel's hair pencil into a dish of 70 per cent. alcohol. The sections can be attached to a slide by placing the slide in a closed chamber over ether. The ether vapor dissolves the celloidin and causes the sections to adhere to the slide.

STAINING AND MOUNTING CELLOIDIN SECTIONS

1. Place sections in safranin solution for 1 day. This safranin solution should be made by dissolving as much safranin in 95 per cent. alcohol as it will take up and then diluting with an equal quantity of water.

2. Rinse sections in 50 per cent. alcohol to remove excess of stain.

3. Transfer them to Delafield's hæmatoxylin for 10 minutes (Delafield's hæmatoxylin is made by dissolving 1 gm. of hæmatoxylin in 6 cc. of absolute alcohol and adding this gradually to 100 cc. of a saturated aqueous solution of ammonia alum. This is left exposed for a week, filtered, 25 cc. each of methyl alcohol and glycerin added, allowed to stand 6 hours, again filtered, and ripened about 2 months before using).

3. Rinse sections thoroughly first in water, then in 35 per cent. alcohol, then in 50 per cent. alcohol.

4. Put them quickly through acid alcohol (1 drop of HCl in 50 cc. of 70 per cent. alcohol).

5. Transfer to 70 per cent. alcohol for about 2 minutes.

6. Transfer to 85 per cent. alcohol for about 2 minutes.

7. Transfer to 95 per cent. alcohol for about 2 minutes.

8. Transfer to absolute alcohol for about 2 minutes.

9. Clear sections in a mixture of equal parts of cedar oil and phenol for at least 2 minutes.

10. Remove excess of clearing solution and mount in balsam.

11. Label slide.

DESILICIFICATION OF HARD WOODY MATERIALS

It frequently happens, even after prolonged maceration or boiling in alkaline solutions, that thin sections of hard roots, stems, woods or fruits are difficult or impossible to procure. This is due to the presence of deposits of silica and other mineral substances that usually occur in woody tissues. Therefore, it is of prime importance that these substances be removed as thoroughly as possible. For this purpose a 10 per cent. aqueous solution of commercial Hydrofluoric Acid (or stronger solutions up to the pure acid for very hard materials) is most useful. Small fruits or short segments of other hard material are placed in this acid (which should be kept in a bottle coated internally with a thick layer of paraffine) for from 3 days to a week, depending on the size of the objects, with one or two changes of the acid. The acid is then washed out thoroughly with running water for 2 to 5 hours. This treatment completely frees the tissues of all mineral deposits without affecting the organic structure.

SCHULZE'S MACERATION PROCESS

This method is employed for the separation of cells. Radial-longitudinal sections, that may be cut with a pen knife, are placed in a beaker or test tube containing 50 cc. of nitric acid of specific gravity 1.3 (about 2 volumes of nitric acid and 1 volume of water will serve the purpose). To this add 1 gm. of chlorate of potash crystals and heat gently until the reddish color which first appears in the tissues has disappeared. Stop the action by pouring the whole of the contents into a vessel containing water and wash well with water. The cells can now be readily separated with dissection needles and mounted in water for examination. Do not mount in glycerine, for it makes the already bleached elements too transparent.

CHAPTER V

LIFE HISTORY OF THE MALE FERN [AN INTERMEDIATE TYPE OF PLANT]

The Male Fern (*Dryopteris Filix-mas*) has long been known to the pharmaceutical and medical professions as the source of the drug **Aspidium,** a most valuable remedy for the expulsion of tapeworm. The parts of the plant employed are the rhizome and stipes which are collected in autumn, freed of the roots and dead portions and dried at a temperature not exceeding 70°C.

Alike with other ferns, the Male Fern shows two phases or generations in its life cycle. The first of these is that which is represented by the more conspicuous plant which we call "the fern." It is in this phase that the spores or asexual cells are produced, hence the plant producing them is called the **sporophyte** (spore-bearing plant). The second phase is that which is represented in the development of an inconspicuous, tiny heart-shaped body which occurs on the surface of woodland soil and which bears the sexual organs in which sexual cells or gametes are produced. This phase is called the **gametophyte** or sexual generation.

HISTORY OF THE SPOROPHYTE OR ASEXUAL GENERATION

Gross Structure of Stem.—The main axis of *Dryopteris Filix-mas* is the creeping underground stem or **rhizome** which is oblique or ascending in habit. It gives off numerous **roots** from its lower and posterior portions and **leaves** from its upper and anterior portions. The leaves of a fern are called **fronds.** Behind the fronds of the present year are to be noted the persistent stalk bases of fronds of previous seasons. The roots are slender, brown and fibrous with semi-transparent tips. They are inserted on the bases of the fronds, close to their junction with the stem. The growing end of the rhizome is called the **anterior extremity** and is marked by the

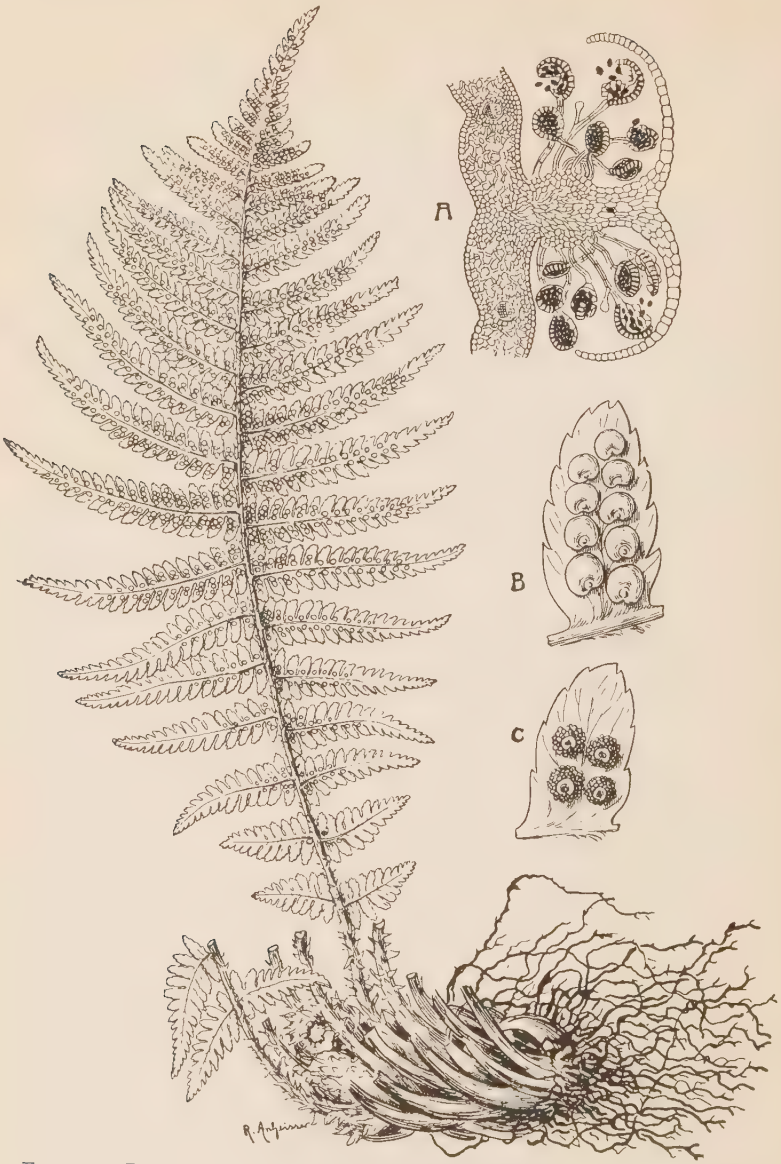

FIG. 15.—*Dryopteris* (*Aspidium*) *Filix-mas*. ⅔ nat. size. *A*, Sorus and portion of pinnule bearing same, in cross section, × 20. (*After Kny*). *B*, Pinnule with young sori, each covered with an indusium. *C*, the same, showing a later stage of the sori, with shrivelled indusia. Both slightly enlarged. (*From Strasburger, Noll, Schenck and Schimper's Lehrbuch der Botanik.*)

presence of an **apical bud** overarched by young fronds. The opposite end is known as the **posterior extremity** and in the living plant is constantly decaying, as the anterior portion elongates.

Gross Structure of the Frond.—Each frond consists of (1) a stem like portion called the **stipe** or leaf stalk and (2) a green, expanded, leafy portion called the **lamina** or blade. The lamina is further divided into a **midrib** bearing its first divisions or lobes which are called **pinnæ.** Each **pinna** (*sing.* for pinnæ) is further divided into secondary lobes which are called **pinnules.** If a pinnule be examined carefully it will be seen to possess **veins** which are arranged in forked fashion. The under side of some of the pinnules will be seen to possess "fruit dots" or **sori.**

Histology of Stem (Rhizome).—Passing from periphery toward the center, the following structures are to be observed, when cross sections are examined under a microscope (see Fig. 17):

1. **Epidermis,** a protective outer covering tissue, composed of a single layer of brownish cells from which are given off scales.

2. **Outer Cortex** (*hypodermis*), a zone of several layers of thick-walled, lignified cells separating the epidermis from the softer underlying tissue. Its main function is to support the epidermis.

3. **Inner Cortex** of several layers of more or less isodiametric cells (cells of nearly the same length, breadth and thickness) with thin cellulose walls and containing stored starch surrounded by a protoplasmic investment. These cells conduct sap by osmosis and store food. Between the cells are to be noted intercellular-air-spaces, many of which contain internal glandular hairs with greenish contents.

4. **Fundamental tissue,** resembling the last in aspect and function.

5. **Vascular Bundles.**—These are elongated strands of water tubes and other tissues which appear in cross section as isolated spot-like areas. If the rhizome be cut lengthwise they will be observed to join each other forming an open network. Branch bundles come off of this network, some of which course into the roots and others into the leaves. Upon reaching the blade of the leaf, they branch in such a way as to form the characteristic veins of that organ. These are of two kinds, viz.: *stem bundles* and *leaf-trace bundles*. The leaf trace bundles are the smaller of the two kinds seen.

Both are of elliptical outline, as seen in cross section, and are embedded in the parenchyma forming the broad central matrix. The stem bundles are comparatively broad and, as viewed in lo ng, tudinal sections, form a continuous network with good-sized meshes each mesh being opposite the point of insertion of one of the leaves (see Fig. 16). In transverse section these bundles are seen to be usually ten in number and arranged in an interrupted circle within the fundamental tissue. The leaf-trace bundles are comparatively narrow and are observed to come off of the stem-bundles and pass out through the cortex into the leaves (fronds). When each bundle is examined under a high-power magnification it is seen to be composed of: (*a*) an *endodermis* or *bundle sheath*, a single layer of cells with yellowish walls and granular contents enveloping the bundle; (*b*) a *pericambium* or phloem sheath of one to three layers of delicate thin-walled cells, rich in protoplasm; (*c*) a *phloem*, a broad zone of tissue formed of *phloem* cells, with thin cellulose walls and protoplasmic contents, which convey sugar in solution from the leaves to the roots, and broader *sieve tubes* which appear polygonal in transverse section and whose function is that of conveying soluble proteins in the same direction; (*d*) a broad central zone, the *xylem* (wood) formed of thin-walled *xylem cells* which conduct sap slowly and store food, and *scalariform tubes* or *tracheids* which conduct crude sap (water with mineral salts in solution) rapidly from the roots to the leaves (fronds). The scalariform tubes in lengthwise view have ladder-like thickenings in their walls which alternate with thin areas. Since the xylem is surrounded by the phloem, the fibro-vascular bundle is of the *concentric-fern* type. Strictly speaking, the endodermis and pericambium are accessory regions, surrounding, but not part of the bundle proper.

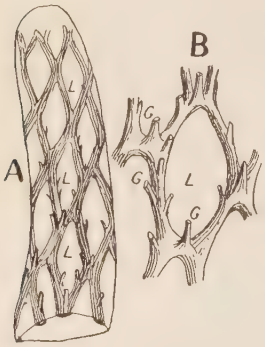

FIG. 16.—*A*, Cylindrical network of vascular bundles in the stem of *Dryopteris Filix-mas*. *B*, A portion of the same more highly magnified. At *L* are the interstices over which the leaves are inserted; at *G* are branches (leaf trace bundles) passing into the leaves from the main vascular bundles. (*Sayre*.)

FIG. 17.—*Dryopteris Filix-mas*. *A*, Transverse section of the rhizome, × 3. *B*, Transverse section of the stipe base, × 5. *C*, longitudinal section through portion of the parenchyma region showing intercellular air-spaces (*lc*) into which oleoresin containing glandular hairs project, × 65. *D*, Transverse section, through a concentric bundle and adjacent parenchyma, × 65. *E*, Longitudinal section through the same, × 65. *a*, cortex; *c* pith; *i*, parenchyma; *y*, concentric bundles; *lc*, intercellular air-spaces; *l* internal glandular hairs; *sp*, scalariform tracheids. (*After Berg.*)

Histology of Growing Apex.—When the bases of the leaves of the current year, the young rolled up leaves of the following year and the large mass of brown scales have been removed from around the apical bud of a well-grown plant, the following structures may readily be observed with a hand lens:

1. The **apical cone** (*punctum vegetationis*), a rounded papilla, which occupies a terminal position in the apical region.

2. The **young fronds,** arranged around the apical cone.

Upon removing the extreme apex of the apical cone with a sharp razor, mouting in dilute glycerine or water and examining under low power, it will be noted that a large pyramidal cell occupies the center of the apical cone. This is the *apical cell* (Fig. 18). The cells surrounding it have been derived by segmentation (cell-division) from it, by means of walls parallel to its three sides; they are termed *segment cells* and in turn undergo further division and redivision to originate the entire stem tissue and leaf tissue. Step by step the tissue cells become modified into epidermal, cortical, bundle and fundamental cells.

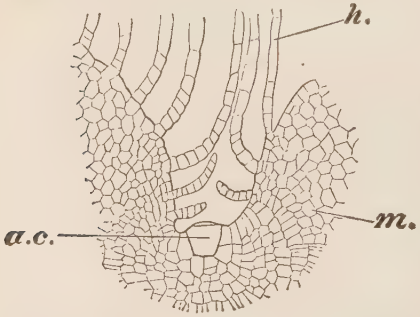

FIG. 18.—Apical cell of a fern rhizome in vertical longitudinal section. *a.c.*, apical cell; *h*, hair; *m*, meristem. (*After Hofmeister.*) *Sedgwick & Wilson's General Biology, Henry Holt & Co.*

Histology of Mature Root.—Transverse sections cut some distance above the root apex will present the following structures for examination: (see Fig. 19).

1. **Epidermis,** of epidermal cells whose outer walls are brown. Some of these cells have grown out as root hairs which surround soil particles and absorb water with mineral salts in solution from the soil.

2. **Cortex,** of many layers of cortical parenchyma cells with brown walls. The outer layers of cells of this region are thin-walled, while the extreme inner ones are lignified and form a sclerenchymatous ring which surrounds the endodermis.

3. **Endodermis**, a single layer of cells tangentially-elongated.

4. **Pericambium** (Pericycle), usually of one or two layers of thin-walled cells containing protoplasm and large nuclei. This region surrounds the single bundle.

FIG. 19.—Cross section of a fern root. Photomicrograph, showing the central, radial diarch bundle and surrounding tissues. Scalariform tracheids of xylem patches (x^1 and x^2); phloem patches (p^1 and p^2); pericambium (*pe*); endodermis (*en*); cortex (*co*). × 300.

5. **Radial fibro-vascular bundle**, consisting of two phloem patches of phloem cells and sieve tubes on either side of two radial xylem arms of scalariform tubes (tracheids) and a few xylem cells.

6. **Lateral rootlets,** which take origin in the pericambium.

Histology of Root Apex.—Microscopic examination shows this region to be composed of soft, pale, growing cells ending in the triangular *apex-cell* of the root. From the free base of the apex cell *segment cells* are cut off as *calyptrogen* cells. These, by dividing, form the *root cap*. The root cap or *calyptra* consists of a mass of loosely attached cells which forms a protective covering around the tip of the root.

From the inner sloping sides of the apex cell the segment cells divide to form three primary meristems. These are (1) the *dermatogen* which, by repeated division of its cells, originates the *epidermis* (outer protective covering of the root), (2) the *periblem*, originating *cortex*, and (3) the *plerome* originating the *bundle* and *related tissue*.

Continuity of Crude Sap Flow. The *crude sap* (water with mineral salts in solution) penetrates the thin walls of the root hairs by osmosis and passes into the interior of hairs, thence into the root xylem and through this to stem xylem, thence through the stem xylem into the leaves.

Histology of Stipe (Petiole).—This, in transverse section, passing from periphery toward the center, presents the following structural characteristics (see Fig. 20):

1. **Epidermis,** a single layer of epidermal cells with dark brown outer walls.

2. **Outer cortex** (hypodermis), a wide band of small cells with lignified walls.

3. **Inner cortex,** similar to inner cortex of stem but devoid of leaf-trace bundles.

4. **Fundamental parenchyma,** similar to same region of the rhizome, in which are embedded a number of *concentric fibro-vascular bundles* arranged in an interrupted circle. Each of these shows a central xylem mass surrounded by an outer phloem mass. Each bundle is enveloped by a *pericambium* and an *endodermis* or bundle sheath.

Histology of a Pinnule.—When transverse and surface sections of the *pinnule* are studied microscopically, the following structural details will be observed:

1. **Upper epidermis,** of wavy-walled, slightly chlorophylloid, flat upper epidermal cells, devoid of stomata (breathing pores), but with rather thick cuticle.

2. **Mesophyll,** a region between the upper and lower epidermis of irregular shaped, chlorophylloid cells, containing abundant chloroplasts. Intercellular-air-spaces are found between various

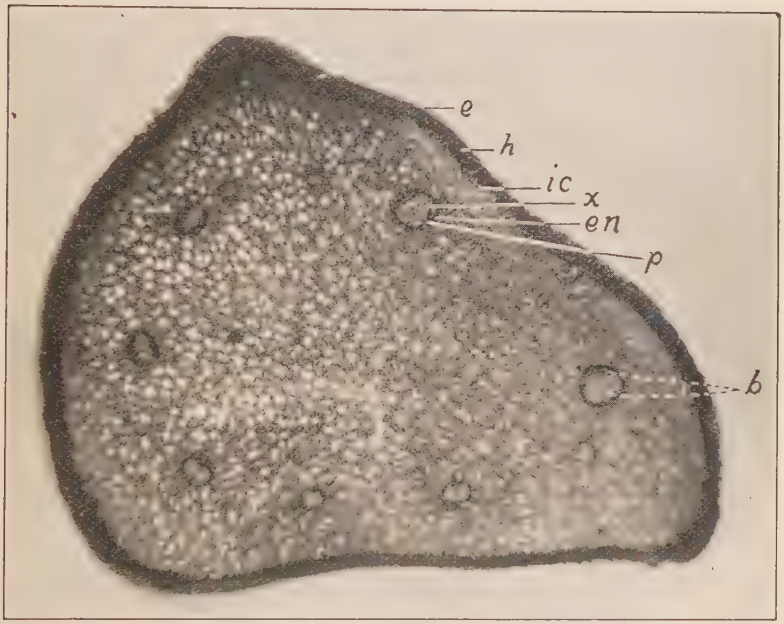

FIG. 20.—Transverse section of stipe of *Dryopteris Filix-mas* showing epidermis (*e*); hypodermis (*h*); inner cortex (*ic*); concentric fibrovascular bundles, one of which is shown at (*b*); endodermis (*en*); pericambium (*p*); xylem (*x*); and phloem (*p*). (Photomicrograph.) × 50.4.

cells which are larger in the lower than in the upper region. Internal glandular-hairs with greenish contents are frequently to be discerned projecting into many of these spaces.

3. **Concentric vascular bundles** or laminar veins, that distribute sap to, and carry sap from the mesophyll. These are seen to be embedded in the mesophyll. The xylem portion of each bundle is

nearest, in end regions of veins, to the upper surface of the leaf and so the bundles approach the collateral type.

4. **Endodermis,** a continuous layer of mesophyll cells which surrounds each bundle and binds it in place.

5. **Lower epidermis** of wavy-walled, flattened, chlorophylloid cells with thin cuticle and many *stomata* (breathing pores). Each **stoma** is surrounded by a pair of crescent-shaped *guard cells* which regulate its opening and closing. The upper and lower epidermis are continuous around the laminar margin.

Comparative Physiology of Root, Stem and Leaf (Frond).—The primary function of the roots of the Male Fern is that of **absorption** of water with mineral salts in solution. The secondary function is that of **support** for the stem, the tertiary, that of **storing foodstuffs** to tide the plant over the season when vegetative activities are lessened. Water is the most essential of all materials absorbed by vegetable organisms. It is found in the soil surrounding the soil particles with certain mineral salts dissolved in it. The delicate root-hairs with thin cellulose walls, protoplasmic lining and sap denser than the soil water, are firmly adherent to these particles. The soil water diffuses through these walls by osmosis and comes into relation with the *outer plasma membrane* or *ectoplasm*, a delicate protoplasmic membrane, which has the power of selecting what it wants and rejecting what it does not need. In this way only such solutes as are of value to the plant are admitted. The water with mineral salts in solution, once within the root-hair protoplast, is called "*crude sap.*" This passes through the hair into the cortical parenchyma cells which are in contact with the scalariform tracheids. It passes from one cortex cell to another by osmosis and, under considerable root pressure, is forced into the scalariform tubes of the xylem. Therein it is conveyed upward by root pressure through the tracheids of the stem bundles into those of the leaves and finally osmoses into the leaf parenchyma cells (mesophyll).

Carbon dioxide (CO_2), from the air, enters the leaf through the stomata. From the stomata it moves through the intercellular-air-spaces to the mesophyll cells which line these, whence it is absorbed. Within the mesophyll cells are found small chloroplasts composed of protoplasm and chlorophyll. The kinetic energy of the sun's rays

is absorbed by the chlorophyll which is thus energized to break up the CO_2 and H_2O into their component elements C, H and O, and rearrange them in such a way as to ultimately form sugar or starch. This process is called **photosynthesis.** According to von Baeyer, CO_2 is split into C and O_2, the C being retained, the O_2 given off. The nascent C is linked with H_2O to form CH_2O (formic-aldehyde); six molecules of this are then united to form grape sugar or glucose ($C_6H_{12}O_6$). The formation of starch may be expressed by the following equation: $6CO_2 + 5H_2O = C_5H_{10}O_5 + 6O_2$. The molecules of glucose and starch contain stored-up energy. A portion of the grape sugar is removed from solution by the chloroplast and converted into starch which is stored up within it; another portion is used to nourish the protoplasm of the cell. But the greater portion of sugar manufactured descends in solution through the phloem cells of the bundles of the veins, mid-rib and stipe to the stem or roots, where it is removed from solution by the action of the leucoplasts which convert it into reserve starch.

Sugar and starch, however, are not the only food materials manufactured in the leaf. Proteins are likewise formed. These are composed of carbon, hydrogen, oxygen, nitrogen, sulphur and sometimes phosphorus. They are formed from grape sugar with the addition of nitrogen and the other elements by the living protoplasm. The source of nitrogen, sulphur and phosphorus is the mineral salts which are found in the crude sap. These proteins descend through the sieve tubes of the veins, *midrib* and *petiole* to the stem and roots, nourishing all of these parts with protein material. The surplus protein material is stored in various cells for future use.

Not all of the water carried to the green cells of the leaves by the tracheids is used in the manufacture of starch. Some of it is employed in chemical reactions taking place within the cells and, some by the protoplasm itself of these cells for the purpose of repair. Whenever there is a surplus of water in the cells of the leaf, some of it escapes into the intercellular-air-spaces as water-vapor. When the humidity of the external atmosphere is less than that of the air-spaces, the water vapor passes out through the stomata. The passage of water vapor through the stomata is called **transpiration.**

All of the living cells of root, stem, leaf as well as other organs of the fern require *oxygen*. This gas enters the plant through the stomata and passes into the intercellular-air-spaces of all of the organs which communicate one with another throughout the entire plant. It diffuses through the cell walls lining these spaces into the cells. Here it unites with the food materials present, oxidizing a portion of them. Oxidation of glucose, etc. is a breaking down process, similar to the combustion of fuel in a furnace, but less intensive and not accompanied by light. The chief products of oxidation are *carbon dioxide* and *water*.

The oxidation of food materials within the cells of organisms is called **respiration.** The carbon dioxide resulting from this process diffuses through the walls of the cells into the intercellular-air-spaces and finally passes out through the stomata. When food materials such as grape sugar undergo oxidation, their stored-up energy (potential energy) is set free as energy in motion (kinetic energy). This energy is utilized by the protoplasm of the cell in carrying on its various kinds of works.

Respiration may be expressed by the following equation:

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O} = \underset{\text{Carbon Dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O}$$

Respiration differs from photosynthesis in the following particulars:

Respiration	*Photosynthesis*
1. It occurs in all living cells.	1. It occurs only in cells containing chlorophyll.
2. It takes place during the day and the night.	2. It takes place only during the day under natural conditions.
3. Oxygen is absorbed and carbon dioxide is set free.	3. Carbon dioxide is absorbed and oxygen is set free.
4. Carbohydrates are combined with oxygen and oxidized.	4. Carbohydrates are formed.
5. Potential energy is released from the food molecules as kinetic energy.	5. Kinetic energy is stored in the food molecules as potential energy.
6. It is a destructive process.	6. It is a constructive process.

There is another process which goes on in the various cells of these organs. It will be recalled that the surplus glucose is stored up in

the form of starch by the leucoplasts and that surplus proteins are also stored. These stored foods are not in the form whereby they can be used by the protoplasm when needed for repair and growth. In order to be serviceable for these purposes, they must be changed into water-soluble products. This is accomplished through the activity of substances called *enzymes* which are manufactured by the cell protoplasm. The process whereby water-insoluble foods are converted into water soluble products is called **digestion.**

Gross Structure and Histology of the Sori and Sporangia.—The *sporangia* or spore cases are found clustered together in circular groups on the under surface of the *pinnules* nearer the mid-vein than the margin. Each group of sporangia is covered with a membranous

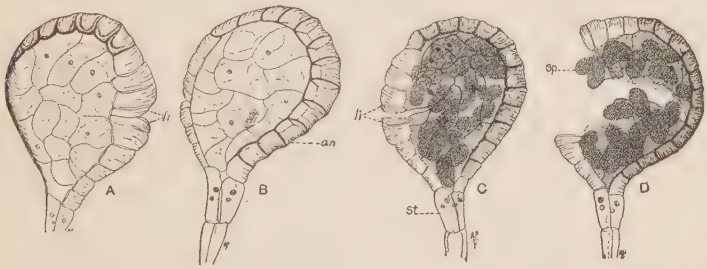

FIG. 21.—Sporangia of an undetermined species of fern; *li*, lip-cells; *an*, annulus; *st*, stalk; *sp*, mature spores. Each of the four nuclei in the upper cells of the stalk is in the terminal cell of one of the four rows of cells that compose the stalk. (*Gager.*)

expansion of the epidermis called the *indusium*. The whole is called a *sorus* (Fig. 15) (pl. sori) and contains many sporangia. Each *sporangium* is composed of: (*a*) the *stalk* of considerable length and usually comprising three rows of cells, outgrowths of the epidermis of the *pinnule;* and (*b*) the *head*, sub-globular and hollow, consisting for the most part of a covering of thin-walled, flattened cells, within which will be noted a marginal ring of cells, with walls having U-shaped thickenings, and called the *annulus*.

Within the sporangium are found the *spores*. Each spore is a single cell composed of an outer brown wall with band-like markings called an *exosporium*, an inner thinner wall or *endosporium*, and within this a mass of protoplasm containing a nucleus.

Rupture of Sporangium and Spore Dissemination.—As was previously indicated, each sporangial head had a row of cells with U-shaped thickenings around the margin called an annulus. As the sporangium matures, the water escapes from the cells, pulling them together and holding the annulus like a bent spring. The thinner walled cells at the side of the spore case opposite the annulus, unable to stand the strain, are consequently torn; the annulus then straightens and a wide rent is made in the sporangium. The annulus then recoils and hurls the spores out of the sporangium. This closes the *sporophyte* generation.

HISTORY OF THE GAMETOPHYTE OR SEXUAL GENERATION

The fern spore, falling upon a moist surface, germinates, producing a delicate, green, septate filament called a *protonema*. One end of this structure shows larger cells, which, by the formation of oblique walls, cut out an apical cell of somewhat triangular shape. This is the growing point of what eventually becomes a mature, green, heart-shaped body called the "*prothallium*" or "prothallus." The prothallium, about the size of an infant's finger nail, develops on its under surface *antheridia*, or male sexual organs, *archegonia*, or female sexual organs, and *rhizoids* or hair-like absorptive structures. The antheridia appear three to five weeks after spore germination. They are hemispherical in shape and are situated among the rhizoids toward the posterior end. Each antheridium consists of a three-celled wall which completely surrounds the *spermatocytes* or mother-cells of the spermatozoids. Within each *spermatocyte* the protoplasm arranges itself in a spiral fashion forming a *spermatozoid*, a spiral, many ciliated, male sexual cell. From two to four weeks after the maturation of the antheridia, the *archegonia* make their appearance toward the indented apex of the lower prothallial surface as outgrowths of the *prothallial cushion*. Since they appear later than the antheridia they are not likely to be fertilized by spermatozoids from the antheridia of the same prothallium. Each *archegonium* is composed of a *venter*, *neck*, *neck canal-cells*, *ventral canal-cell*, and *ovum* or egg-cell (see Fig. 23). The neck is composed of cells

arranged in four rows, forming a cylinder, one layer of cells thick. This protrudes from the surface of the prothallium and encloses the neck canal-cells and ventral canal-cell. The ovum is embedded in the prothallial cushion just beneath the ventral canal-cell. Upon the maturation of the archegonium, the canal cells are transformed

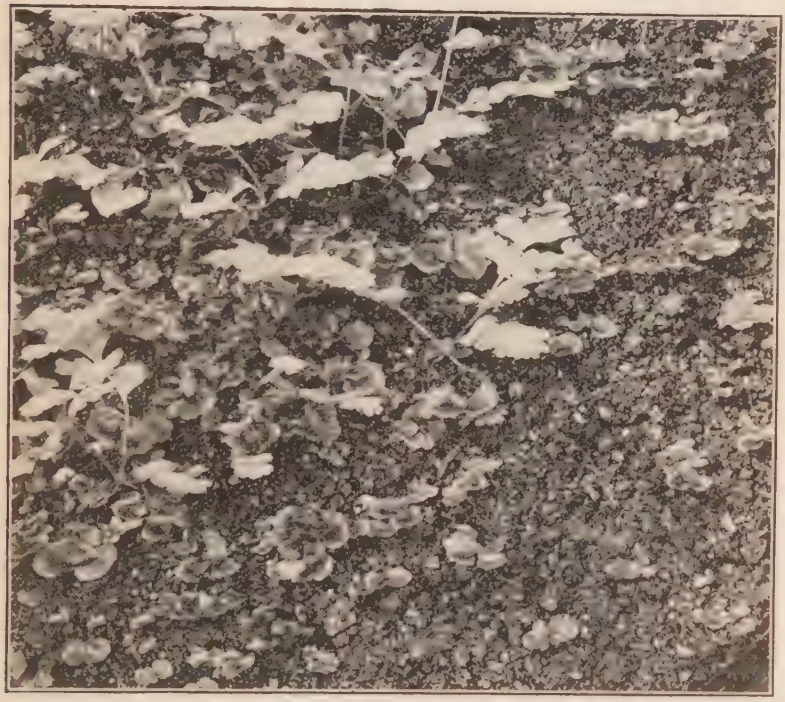

FIG. 22.—Group of fern prothallia growing on the surface of soil. Young sporophytes are developing on some of the prothallia. (*Gager.*)

into a mucilaginous substance which fills a canal extending from the outside opening (mouth) to the ovum.

During wet weather the mature antheridial wall bursts open and the many ciliated *spermatozoids* escape into the water. These, moving in the water, are drawn by the chemotactic malic acid to the mouths of the archegonia of another prothallus, and, passing down

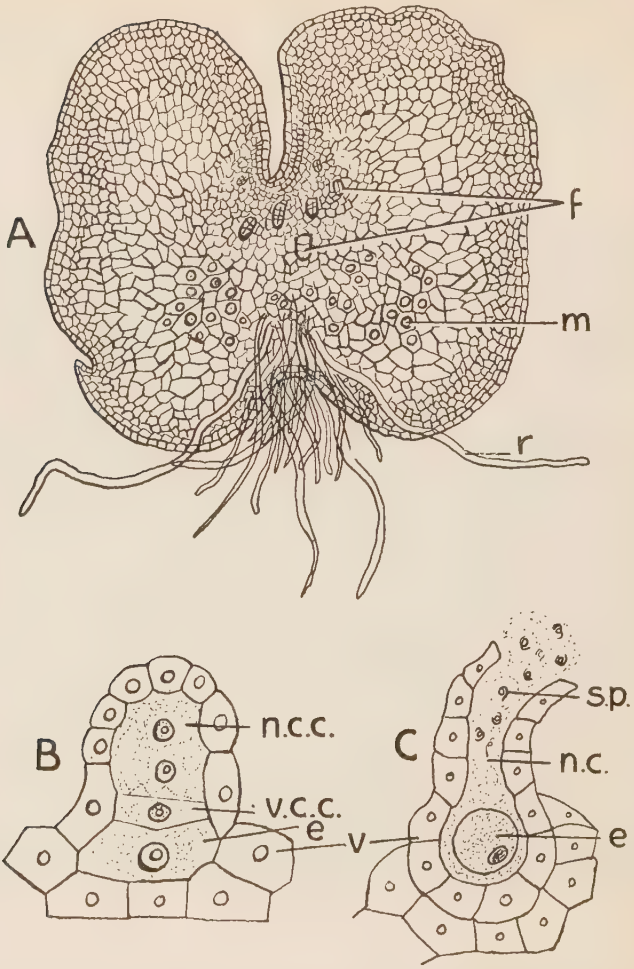

FIG. 23.—*A*, under surface of a fern prothallium showing archegonia (*f*), antheridia (*m*) and rhizoids (*r*); *B*, immature archegonium showing binucleate neck canal cell (*n.c.c.*), ventral canal cell (*v.c.c.*), and egg (*e*); *C*, mature archegonium showing sperms (*sp.*) moving through neck canal (*n.c.*) toward ovum (*e*); and venter (*v*). All highly magnified.

the canal of each of these, gather around the ovum. One, probably the best adapted, fuses with the ovum and fertilizes it forming an *oöspore* or fertilized egg. This completes the gametophyte generation.

ORIGIN OF NEW SPOROPHYTE PLANT FROM FERTILIZED EGG

The fertilized egg now divides into hemispheres, then into quadrants and again to form eight cells arranged in a spherical mass and called *octant cells*. The octant cells divide to form a many celled *embryo* which shows the following parts: *foot rudiment, root rudiment, stem or rhizome rudiment, hair rudiments,* and *first leaf.*

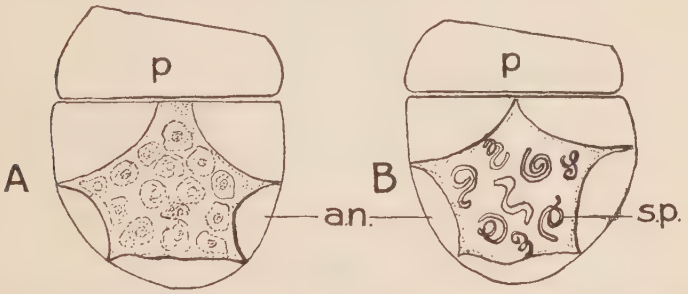

FIG. 24.—*A*, median longitudinal section through immature antheridium, and cell of prothallium showing prothallial cell (*p*), and antheridial wall surrounding a number of spermatocytes; *B*, similar section through mature antheridium and cell of prothallium showing fully developed spermatozoids (*sp.*) enclosed by wall of antheridium (*an*). Both highly magnified.

Growth of Embryo into Mature Sporophyte.—The foot rudiment develops into the *foot* which obtains nourishment from the prothallium, upon which the young sporophyte is for a time parasitic. The root rudiment becomes the *first root* which grows downward into the soil. The stem rudiment becomes a *rhizome* which, with the first leaf, turns upward. In a few weeks the prothallus decays and the sporophyte is established as an independent plant. More leaves (fronds) and roots are developed and ere long continued growth results in the formation of a mature sporophyte which presents for examination: (1) a *subterranean stem* or *rhizome*, (2) *roots;* and (3)

aerial fronds, each of which consists of a *stipe* or *petiole* and a *lamina* or *blade*, the latter divisible into *pinnæ* or *lobes* and *pinnules*, upon which last *sori* are developed.

FIG. 25.—*Pteris* (The brake fern). *A*. Early stage in development of embryo from oöspore showing division of octant cells to form: *f*, foot rudiment; *s*, stem rudiment; *b*, first leaf rudiment; *w*, root rudiment. *B*. Later stage in the development of embryo: *f*, foot embedded in archegonium (*aw*) of prothallus (*pr*); *s*, young stem; *b*, young first leaf; *w*, young root. *A*, after Kienitz-Gerloff; *B*, after Hofmeister. (*From Strasburger's Lehrbuch der Botanik.*)

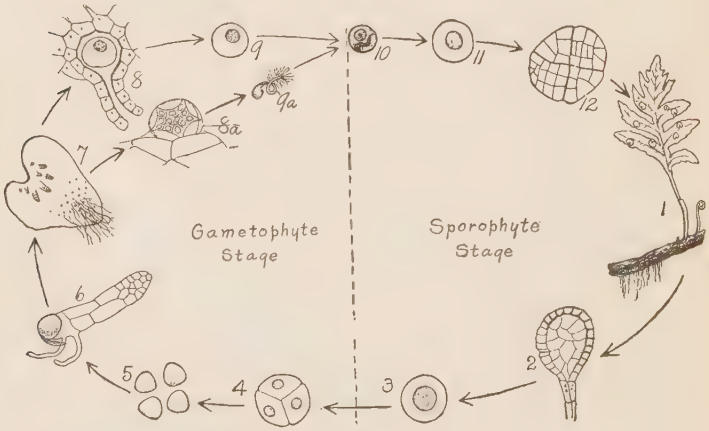

FIG. 26.—Diagram of life-cycle of a fern. (*Gager.*)

Alternation of Generations.—It will be observed that in the life cycle of the Male Fern there occur two distinct generations, one, a

sporophyte or asexual generation which begins with the oöspore and ends with the dispersion of asexual spores; a second, the gametophyte or sexual generation, beginning with the protonemal outgrowth of the spore and ending with the fertilization of the egg to form an oöspore. The sporophyte gives rise to the gametophyte which in turn gives origin to the sporophyte. This is called "*alternation of generations.*"

CHAPTER VI

VEGETABLE CYTOLOGY

Vegetable Cytology treats of plant cells and their contents.

THE CELL AS THE FUNDAMENTAL UNIT

Robert Hooke, an Englishman, in 1665, first described and figured cells. He observed compartments regularly arranged in rows in thin sections of cork, and, likening these to the rooms of monasteries, named them cells. In 1831, Brown, another Englishman, discovered the nucleus which he found in a number of the plant cells.

Schleiden, a German, in 1838, showed the cell to be the unit of plant structure. The following year Schwann, another German, showed that the bodies of animals are also composed of cell units. The bodies of all plants and animals are composed of one or more of these fundamental units. Each cell consists of a unit mass of living matter to which Von Mohl gave the name of *protoplasm* in 1851. The cell protoplasm may or may not have a cell wall surrounding it. While most plant cells contain a nucleus and some contain a number of nuclei, the cells of the blue-green algæ and the bacteria have been found to lack definitely organized structures of this kind but rather contain chromatin within their protoplasm in a more or less diffuse or loosely aggregated condition.

A TYPICAL PLANT CELL

If we peel off a portion of the thin colorless skin or *epidermis* from the inner concave surface of an onion bulb scale, mount in water and examine under the microscope, we find it to be composed of a large number of similar cells which are separated from one another by means of lines, the bounding cell walls. Under high power each of these cells will exhibit the following characteristics:

An outer wall, highly refractile in nature and composed of *cellulose* which surrounds the living matter or *protoplasm* (see Fig. 27). This wall is not living itself but is formed by the living matter of the cell. Somewhere within the protoplasm will be noted a denser-looking body. This is the *nucleus*. Within the nucleus will be seen one or more smaller highly refractile and definitely circumscribed *bodies*, the *nucleolus* or *nucleoli*. The protoplasm of the cell outside of the nucleus is called the "*cytoplasm*." It will be seen to be clear and

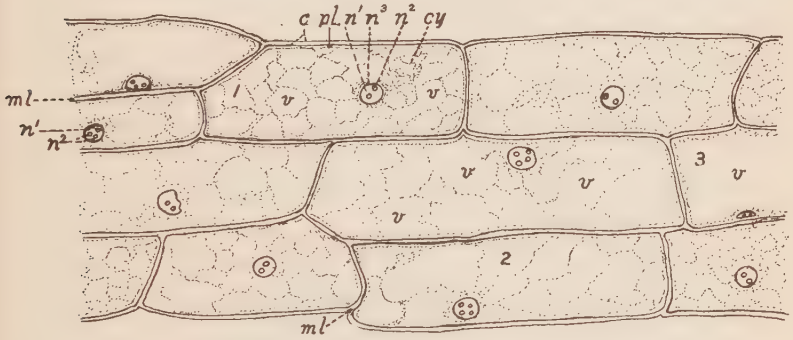

FIG. 27.—Portion of the inner epidermis of an Onion bulb scale, showing cells at various stages of maturity. Young cell (1); old cell (3); cell intermediate in age between 1 and 3 (2); cell wall (*c*); outer plasma membrane (*pl*); middle lamella (*ml*); nucleus (n^1); nucleolus (n^2); nuclear membrane (n^3); cytoplasm (*cy*); vacuole (*v*). Note that the young cell (1) shows numerous small vacuoles and a spheroidal nucleus near center of cytoplasm. In 2 (cell of intermediate age) the cell has enlarged, larger vacuoles have formed through the bursting of films of cytoplasm separating smaller ones, and the nucleus has moved toward the cell wall. In 3, the films have all burst, the cytoplasm and nucleus have been pushed up against the cell wall, the nucleus is flattened out, and a large vacuole appears in the center of the cell.

granular-looking. Within the cytoplasm will be observed a number of clear spaces. These are *vacuoles* and because they are filled with *cell sap* (water with nutrient substances in solution) are called "sap *vacuoles*." The vacuoles appear as tiny droplets in young cells but grow with the cell, becoming larger as the cell increases in size, then fusing with each other until, in a fully mature old cell, one large vacuole is present in the center of the cell with protoplasm and nucleus pushed up against the cell wall.

Protoplasm is in intimate relation to water. The reaction of the cytoplasm to a bounding film of water between it and the cell wall forms the *outer plasma membrane* or *ectoplasm*, a clear, homogeneous, outer band of cytoplasm; the reaction of cytoplasm to the water within the sap vacuoles forms the *vaculor membranes;* the reaction of the dense protoplasm of the nucleus to the water in the cytoplasm around it forms the *nuclear membrane.* All of these membranes are bounding films of protoplasm belonging to the region in contact with water and are collectively termed *plasma membranes.* Upon mounting another portion of epidermis in iodine solution, removing the excess of stain and adding a drop of sulphuric acid and then examining under high power, we note that the cell walls of cellulose are stained a deep blue. A yellow line is evident in the middle of each cell wall and separates each cell from its bounding cells. This line is the *middle lamella* which is composed largely of *calcium pectate.*

TYPICAL GREEN CELLS

Excellent material for the microscopic study of green cells of plants is to be found in the leaf of *Elodea*, a fresh water plant, found in ponds and house aquaria. The leaves of this plant are small enough to be mounted beneath an ordinary cover glass on a microscopic slide. They are oblong to oblong-ovate and occur in whorls of 2 to 4 along a slender, elongated stem.

When one of these is detached, mounted in water and examined under low power magnification, it is seen to be two layers of cells thick, except along the margin, where only one layer of cells is to be observed and in the central midrib region, where there occur several layers of narrow cylindrical cells. The *cells* are arranged in rows and vary in size, being shorter and broader toward the midrib and longer and narrower near the margin. Projecting tooth-like cells occur along the margin. The cells of the lower surface appear about twice as broad as those of the lower surface. Each cell is separated from its neighbors by means of transparent *cell walls.* Just as in the onion epidermis, what appears to be a single partition wall between two cells is really two cell walls separated by a *middle lamella.*

If some of the larger cells are now examined under high power magnification, each is found to be brick-shaped. Beneath the cell wall will be seen a narrow zone of *cytoplasm* containing numerous, green, ovoid bodies, the *chloroplasts*. Each chloroplast is a dense, porous, mass of protoplasm containing the green pigment, *chlorophyll*. In some of the cells the protoplasm will be found to be in motion (*rotation*), carrying the chloroplast along with it. The *nucleus* will be observed as a clear, somewhat hemispherical shaped body embedded in the cytoplasm. A *nucleolus* will be seen within the nucleus.

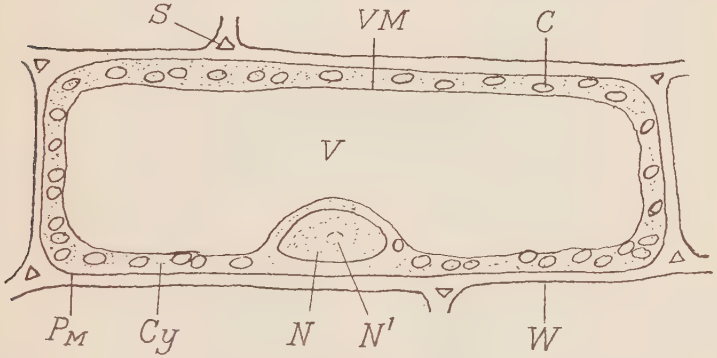

FIG. 28.—A typical green cell of *Elodea*. Cy, cytoplasm; N, nucleus; N, nucleolus; C, chloroplast; Pm, outer plasma membrane; VM, vacuolar membrane; V, sap vacuole; W, cell wall; S, intercellular-air-space. Greatly magnified.

The center of the cell is occupied by a large *sap vacuole* containing a watery solution of salts and other nourishing substances. A clear *vacuolar membrane* lines the inner surface of the cytoplasm, while another clear membrane, the *outer plasma membrane*, lines the outer surface of the cytoplasm.

If the leaf be boiled in water so as to kill the plasma membranes and make them permeable and then mounted in dilute iodine solution and examined under the microscope, bluish to bluish-black bodies will be observed in the chloroplasts. These are starch granules. They have been formed in the chloroplast through the agency of chlorophyll and sunlight by the process called photosynthesis. This process is discussed more fully in another part of the book.

THE AMŒBA

Amœba is a microscopic organism rarely more than $\frac{1}{50}$ in. in diameter, classified by most biologists within the phylum, **Protozoa,** a group of unicellular animals. It is found in stagnant water almost universally, where it adheres to weeds, dead leaves, or other submerged objects.

If a drop of Amœba culture be placed on the slide, covered with a cover-glass, and the mount searched under low power, an Amœba should be found.

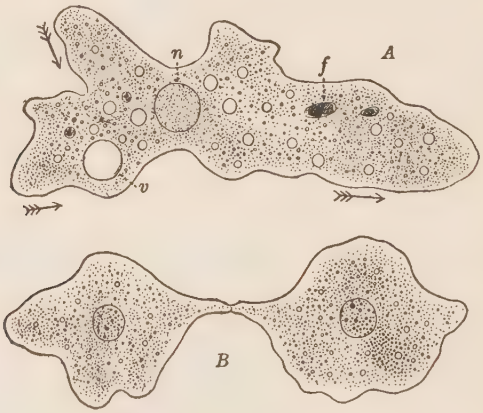

FIG. 29.—The Amœba. *A*, An amœba moving in the direction of the arrows; *n*, nucleus; *v*, contractile vacuole; *f*, food within food vacuole. *B*, the process of fission in Amœba, a nucleus in each half. B, after Jordan, Kellogg and Heath. (*From Bergen and Davis Principles of Botany.*)

The beginner in microscopy is very likely to overlook an Amœba altogether, or to think that every little irregular, clear spot in the field of view is one. When a clear object is seen which is never the same in outline in consecutive moments, one is certain of viewing Amœba.

Move the slide if necessary so as to bring the organism into the center of the field of view. Swing on the clips and bring the high-power objective into position. Focus.

Note that Amœba is a one-celled organism devoid of a cell wall, hence a naked mass of *protoplasm*. *Protoplasm* is a semifluid, viscid,

granular like substance, in which life resides. It is shown by chemical analysis to consist mainly of certain substances known as proteids, bodies of extreme complexity in chemical constitution, examples of which are white of egg or the albumen of blood serum. Besides proteids, the protoplasm of Amœba contains fats and small proportions of mineral matters such as salts of potassium, calcium, magnesium and iron. It also contains a large proportion of water, called *water of organization.*

Protoplasm is caused to shrink by strong alcohol, which withdraws the water of organization. It is coagulated by heat and dissolved by prolonged treatment with weak acids or alkalies.

Note that the protoplasm of the Amœba consists of an outer non-granular portion called the *ectoplasm* and an inner portion called the *endoplasm.* Within the endoplasm is to be found the *nucleus* which in the Amœba is difficult to discern without the use of special stains.

Observe the Amœba as it moves and find out whether the direction of movement is in one line or several.

Note that Amœba moves by extending protoplasmic processes called *pseudopodia* (false feet). At a particular point the ectoplasm is pushed out in the form of a small pimple-like elevation; this increases in size, still consisting of ectoplasm only until, at last, granules from the endoplasm stream into it and the projection or pseudopod comes to possess the same structure as the rest of the Amœba. This method of movement is called *amœboid movement.* The same kind of protoplasmic movement is shown by the slime molds and white blood corpuscles.

Note that when the organism comes in contact with a diatom or any other particle of food pseudopodia are extruded and the food is enveloped, so sinking into the cytoplasm. The food is taken in with a small amount of water, which forms a surrounding bubble or *food vacuole.* This constitutes the first step in the process of *nutrition* and is called *ingestion.* If watched sufficiently long, the protoplasm of the diatom or substance of the food particle ingested is slowly dissolved or digested through the agency of some enzyme or enzymes within the endoplasm. As it moves on, the Amœba ejects

or expells the cell wall of the diatom or any other insoluble substance.

An *enzyme* is a substance of biologic origin which has the property of causing a change in its surrounding medium without becoming involved itself. Through enzyme action the previously water insoluble (colloidal) protoplasm or food of the Amœba is broken down into water-soluble (crystalloidal) substances which are capable of diffusion. The process whereby water-insoluble foodstuffs are made water-soluble through enzymic action is called *digestion.*

Mineral matters are taken in by the Amœba with its food in the form of a weak, watery solution. The next step is for the organism to rearrange the elements of digested food, mineral salts and water in such a way as to form new particles of living protoplasm. These are deposited among the pre-existing particles and so *assimilated* or converted into the living substance of the Amœba. One effect of this formation of new protoplasm is *growth.* This process of growth by the interposition of new particles among the old ones is called *intussusception.* All living things, both animals and plants, grow or increase in size by this method.

Minerals or other organized non-living things grow by a deposition of successive layers on their original surfaces. This process of growth is called *accretion.*

Look for a large, clear, pulsating structure or space within the protoplasm of the Amœba. This is the *contractile vacuole.*

Alike with all other living organisms, Amœba is continually undergoing destructive as well as constructive changes. Every time it extrudes pseudopodia or performs work of any kind, a portion of its protoplasm is broken down by oxidation, which is accompanied by a release of energy. The nitrogenous waste in solution, resulting from the oxidation of protoplasm, makes its way to the contractile vacuole and is expelled by its contraction. This function of getting rid of nitrogenous waste is called *excretion.*

In order that the oxidation of protoplasm, referred to in the preceding paragraph, may take place, a constant supply of oxygen is essential. The water in which Amœba lives contains this gas in solution. Now, the protoplasm of the Amœba (as well as other living organisms) is continually forming carbon dioxide. When two

gases are separated from one another by a porous septum, an interchange takes place between them, each diffusing into the space occupied by the other. The process of gaseous interchange is precisely what takes place between the H_2O in the surrounding water and the CO_2 in the interior of the Amœba, the protoplasm acting as a porous partition. This gaseous interchange whereby this organism

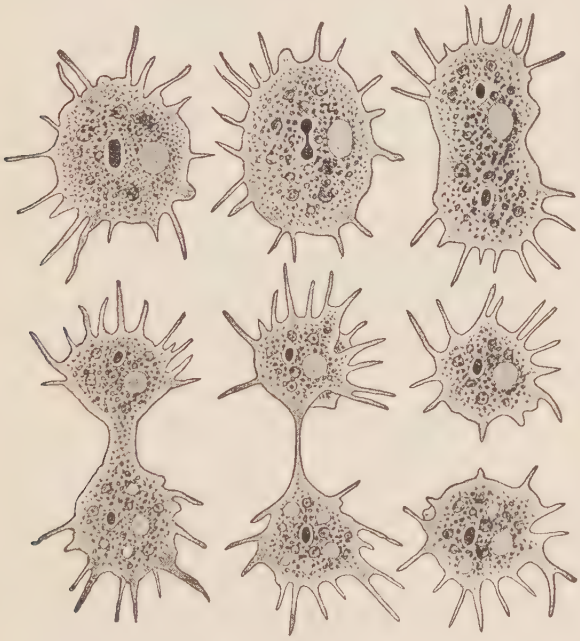

FIG. 30.—Stages in the division of *Amœba polypodia*. (From *Marshall, after Schulze and Lang.*)

takes in oxygen and gives carbon dioxide off is called *respiration* or *breathing*. The oxygen taken in by the Amœba oxidizes the complex carbon compounds within its body with an accompanying release of energy.

In order that the race of Amœba may not be exterminated, there must be some provision whereby its numerous casualties may be balanced. In other words, Amœba must produce new individuals like itself. This function is called *reproduction*.

Amœba reproduces itself by the simplest method of reproduction, known as *simple* or *binary fission*. At first the nucleus divides into two; then the whole organism elongates, the two nuclei at the same time traveling away from one another; next a furrow appears across the middle of the elongated body between the nuclei; the furrow deepens until finally the organism separates into two separate Amœbæ, which henceforth lead an independent existence.

Under unfavorable circumstances, such as the drying up of the water in pools in which it exists and the approach of cold weather, the Amœba draws in its pseudopodia, loses most of its water content, becomes spherical in shape and develops on its outer surface a thick resistant wall called a *cyst*. Inside of the cyst the nucleus undergoes division to form a large number of nuclei. Cells walls then appear dividing up the cell contents into as many little Amœbas called Amœbulæ as there are nuclei. Upon the approach of favorable conditions, these Amœbulæ escape by rupture of the cyst, each developing into an active Amœba. This process is called *sporulation* and represents another method of reproduction shown by the Amœba.

PROTOPLASM AND ITS PROPERTIES

Protoplasm, or living matter, is the more or less semi-fluid, viscid, foamy, and granular substance in which life resides. It is the "physical basis of life."

Protoplasm cannot be analyzed chemically. Dead protoplasm, which is the material examined when protoplasm is subjected to reagents in the procedure of chemical analysis, consists of a variety of different chemical compounds including proteins, carbohydrates, fats, salts of potassium, magnesium, calcium and sometimes iron, etc., and water.

The peculiar properties which distinguish protoplasm from non-living matter are as follows:

1. **Structure.**—Protoplasm invariably exhibits structure. No portion of it, however small, has been found to be homogeneous. Each advance in microscopical technique reveals new complexities. The protoplasm of a single cell, far from being a single unit, must rather be looked upon as a microcosm.

2. **Metabolism.**—Perhaps the most significant peculiarity of living matter is found in its instability and the chemical changes which continually go on within it. It is constantly wasting away, and as constantly being built up. These losses and gains are not upon the exterior surface but throughout its mass. Its growth and renewal are by *intussusception*, or the taking in of new particles and storing them between those already present. Inorganic substances, such as crystals on the other hand, grow by *accretion*, *e.g.* through the addition of similar material in layers on their outer surfaces. A bit

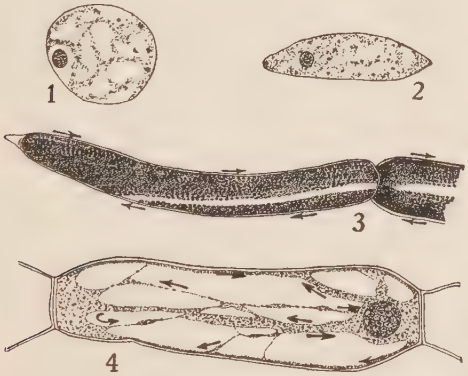

FIG. 31.—Protoplasmic movement. 1 and 2, nuclei from the tapetal plasmodium of the spore case of *Botrychium*, 1, in the usual form, and 2, flattened while entering a crevice between spore-groups; 3, cell from *Nitella* showing cytoplasmic rotation as indicated by the arrows; 4, cell from stamen-hair of the Spiderwort (*Tradescantia*), showing circulation of the cytoplasm as indicated by the arrows. (*After Stevens.*)

of protoplasm may retain its indentity while all the matter of which it is composed is changed over and over. It is like a whirlpool or wave in a river which remains the same while the water of which it is composed changes continually. Metabolism has been aptly defined by Huxley as the whirlpool character of the organism. It may also be defined as the series of processes concerned with the building up and breaking down of living matter. To those processes concerned with the building up of protoplasm, such as absorption, photosynthesis, digestion and assimilation, the term *anabolism* is applied. Another term for anabolism is *nutrition*. To those

processes which involve the breaking down of protoplasm, such as respiration, excretion and secretion, the term *katabolism* has been given.

3. **Irritability.**—This is the property possessed by protoplasm of responding to a stimulus. All living matter responds to stimulation. When matter fails to be irritable or responsive to stimuli, we declare it to be dead. The stimuli that excite reactions in living matter are of two kinds, viz., intrinsic and extrinsic.

Intrinsic stimuli are inherited stimuli, being carried by the chromosomes from parent to offspring. They determine that the plant shall conform to a particular type, carry on certain activities, pass through a definite life cycle, and detach a portion of its own substance for the formation of new individuals of its kind.

Extrinsic stimuli initiate, inhibit, accelerate or modify the effects of intrinsic stimuli. They comprise agents of the external world such as cold, heat, chemicals, food, water, light, oxygen, electricity, gravity, etc.

Tropisms.—The irritable reactions manifested by protoplasm and living things to the effects of these external agents are termed *tropisms* and will now be considered briefly.

Thermotropism is the response of living substance to the stimulus of temperature. All living substance is influenced by variations in temperature. Freezing disintegrates it while excessive heat causes its coagulation. Active vital phenomena are therefore only evident within these extremes, the limits differing depending upon the endurance of the organism under examination. The lowest temperature at which the activity of an organism becomes evident is known as the *minimum*, that at which the activities are at their best, the *optimum*, and the highest at which they can be continued, the *maximum*. Some plants are able to endure greater extremes of temperature variation than others because of special adaptations. Thus, certain bacteria produce spores which resist exposure for an hour to the temperature of liquid hydrogen (−225°C.) or to that of a hot air oven at 100°C. Many higher plants can endure moderately low temperatures by the development of a hairy covering; others which are killed by frost produce seeds which can endure rigid cold, still others adapt themselves to existence through periods of

cold by passing through a latent stage in the form of bulbs, like the Squill or the Lily, or rhizomes, as the Blood Root or the Hellebores.

Chemotropism is the response of protoplasm to chemical stimulation. Any substances that possess the property of producing a deleterious effect upon protoplasm are termed *poisons*. Poisons may effect an immediate destructive combination with living substance when they are called *caustics*, or they may have an exciting or depressing effect which may eventually prove destructive without visible structural change, when they are termed *toxins*. Caustics may liquefy the protoplasm, as the alkalies, or coagulate it, as the acids or salts of metals. When well diluted, chemicals may occasion no destructive effects, but may call forth positive or negative responses, known as positive or negative chemotropism.

Thus, Pfeffer, working with the motile sperms of ferns, found that if a capillary tube, containing a solution of malic acid, be introduced into water containing them, the sperms moved toward it and entered. It is now generally believed that the motile male sexual cells of all flowerless plants are attracted to the appropriate female sexual cells by means of positive chemotropic influences. Among flowering plants, it has been observed that pollen grains brought by various agencies from anthers to stigmas of certain plants of different species will not germinate, but when they are carried from one plant to another of the same species or variety, they readily send their pollen tubes through the stigma and style to the ovule below. In the former instance, negative chemotropism is illustrated, while in the latter, positive chemotropism is shown.

Sitotropism is the reaction of living matter to the influence of food. Hertwig found that if a fine capillary tube be filled with a 1 per cent. solution of asparagin or beef extract and held in contact with a drop of water containing certain bacteria, a mass of these soon plugged the mouth of the tube. His experiment shows that these organisms moved from a poorer to a richer nutrient medium in response to a positive sitotropic influence.

Oxytropism is the response to the stimulating influence of oxygen. We see evidence of this everywhere in nature. No living thing can continue to exist without this element. A mistaken idea is often

prevalent regarding obligate anaërobic bacteria. Like all other bacteria or organisms, these plants require oxygen but can only assimilate it in its combined form. The tetanus bacillus is a good example. Aërobic bacteria, on the other hand, require free (uncombined) oxygen for assimilative purposes. Thus the tetanus organism (an *anaërobe*) grows in the depth of culture media, whereas the tubercle bacterium (an *aërobe*) grows only on the surface.

Hydrotropism is the response of protoplasm to the stimulus of water. This reaction is seen in both positive and negative phases in the slime molds. The vegetative stage of these lowly plants is characterized by a naked, many nucleated mass of protoplasm, confining itself to the moist crevices of rotten logs, etc. until the surface of the substratum becomes wet, when and only when it will emerge. As soon, however, as its fruiting stage begins, the whole protoplasmic mass wells up from the substratum, away from moisture. The roots of young seedling plants show positive hydrotropism by growing toward moisture in the soil.

Heliotropism is the response of living substance to the stimulus of light. The stems of higher plants tend to grow toward the light and are, therefore, positively heliotropic, whereas the roots grow away from the source of light and so are negatively heliotropic.

Geotropism is the response of protoplasm to the stimulus of gravity. Roots of Pteridophytes and seed plants invariably grow downward toward the center of gravity and so are positively geotropic. The fruiting organs of the fungi and the main stems of higher plants tend to grow perpendicular to the earth's surface and so are negatively geotropic. Branches of stems that assume a relation parallel to the earth's surface are *diageotropic*. The Lima Bean, Sarsaparilla, Poison Ivy, and other plants whose stems twine about supports exhibit *lateral geotropism* in their horizontal curvatures.

Galvanotropism is the reaction of protoplasm to electrical stimuli. In this connection it may be said that the degree of response bears a definite relation to the intensity of the stimulus. No visible external electrotropic reactions have been observed in higher plants, although when their cells are examined microscopically, the reaction becomes manifest. Kühne has shown that when an electric current

is passed through the hairs of the Spöderwort, the cytoplasm becomes gathered into small globular masses.

Thigmotropism is the response of living matter to mechanical stimulation. Examples of this form of irritability appear to be far

FIG. 32.—Venus fly-traps, *Dionæa muscipula*, growing in field near Wilmington, N. C. (*Photograph by Steckbeck and Palmer.*)

less common among plants than among animals. Certain species of *Mimosa*, *Oxalis*, *Drosera*, *Desmodium* and *Dionæa muscipula*

exhibit this phenomenon to a marked degree. A few instances only will be considered. When the tendrils of climbing plants come into contact with the uneven surface of solid bodies they are induced to coil. When the tentacles on a modified leaf of the Sundew (*Drosera*) are stimulated mechanically by an insect or artifically they are induced to curve over. If a good plant of the Venus Fly-trap

FIG. 33.—A sensitive plant, *Mimosa Spegazzini*. Note the expanded condition of the leaves before stimulation. (*After Steckbeck.*)

(*Dionæa*) is selected, it will be seen to possess leaves, the terminal portions of which are modified as traps for catching insects (Fig. 32). Hairs will be seen projecting from the upper surface of each valve of the hinged blade. If one of these hairs is touched with a pencil no reaction will be evident but if, after a lapse of twenty seconds, the hair is touched again, the 2 valves close. If the stamens of Berberis be touched near the base during their pollen shedding stage they will be observed to curve toward the stigma.

The most highly specialized form of thigmotropism observed in plants appears to be found in *Mimosa Spegazzini*, a member of the Bean family. According to Steckbeck "when a mechanical stimulus, such as a forceps pinch, is applied to one of the terminal secondary leaflets after a latent period of less than ¼ second, the leaflet

FIG. 34.—*Mimosa Spegazzini*. After the application of a stimulus. Compare with Fig. 33. (*After Steckbeck.*)

stimulated rises and its partner almost at the same time. The stimulus is then carried down the midrib, the pairs of secondary leaflets closing in order; in 9 seconds all the secondary leaflets have closed, the midribs converge, followed in 3 seconds by a drop of the entire leaf. The stimulus moves up the other leaflet with the result that the secondary leaflets close in order. In 20 seconds after the stimulus has been applied all of the secondary leaflets are closed.

The stimulus is propagated through the stem to other leaves."[1] (cf. Figs. 33 and 34.)

4. **Reproduction.**—Protoplasm also shows a very remarkable ability to increase and to give off detached portions which retain

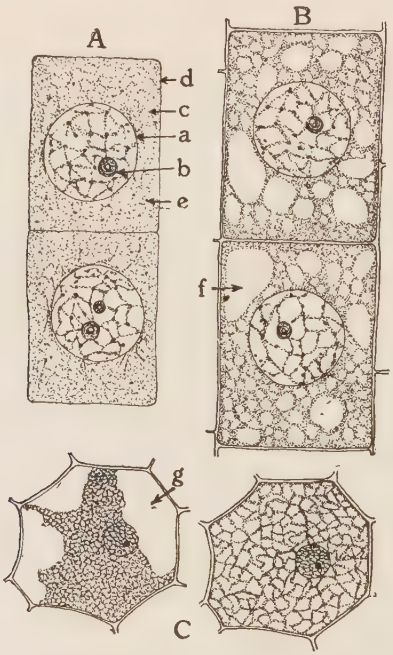

FIG. 35.—*A*, embryonic cells from onion root tip; *d*, outer plasma membrane; *c*, cytoplasm; *a*, nuclear membrane enclosing the thread-like nuclear reticulum; *b*, nucleolus; *e*, plastids (black dots scattered about). *B*, older cells farther back from the root tip. The cytoplasm is becoming vacuolate; *f*, vacuole. *C*, a cell from the epidermis of the mid-rib of *Tradescantia zebrina*, in its natural condition on the right, and plasmolyzed by a salt solution on the left; *g*, space left by the recedence of the cytoplasm from the wall; the plasma membrane can now be seen as a delicate membrane bounding the shrunken protoplast. All highly magnified. (*Stevens.*)

the infinitely complex peculiarities and properties of the original. The process, moreover, may be continued indefinitely. These

[1] "The comparative histology and irritability of sensitive plants" by D. W. Steckbeck in Contributions from The Botanical Laboratory of the U. of Pa., vol. IV, No. 2, p. 217, 1919.

detached portions may be of the nature of sexual cells which unite to form a cell called a zygote or oöspore from which a mature individual develops or of the nature of asexual cells detached singly or enmasse which eventually develop into mature individuals.

Other physiological characteristics might be added, but the above are mentioned as the most satisfactory criteria by which living may be distinguished from non-living matter.

PROTOPLASMIC CELL CONTENTS

The name "*protoplast*" has been given to the entire living or protoplasmic matter within a single cell. The protoplast consists of six well-differentiated portions, viz:

(*a*) **The Cytoplasm,** or the foamy, often granular matrix of protoplasm outside of the nucleus. Embedded in the cytoplasm are non-protoplasmic bodies called inclusions. The most prominent of these are the *vacuoles* which are spaces within the cytoplasm containing either a watery solution of nourishing materials (*cell sap*) or, in old cells, air.

(*b*) **The Nucleus,** a denser, definitely circumscribed region of protoplasm containing nucleoplasm which consists of *chromatin*, a substance staining heavily with certain basic dyes, adhering in the form of granules to a network of *linin*. Nuclear sap, consisting of a watery solution of nourishing substance is also found in the nucleus. The nucleus may be regarded as the superintendent of the activities of the cell. It is usually spherical in shape but in some plant cells is ellipsoidal, stellate, discoidal or elongated. The chromatin is the substance which carries those characters or factors from parent to offspring which determine that the offspring shall resemble its parent or parents and past ancestors.

(*c*) **The Nucleolus,** a small body of dense protoplasm within the nucleus. Sometimes two or more nucleoli may occur within a nucleus.

(*d*) **The Plastids,** composed of plastid plasm; small, discoidal, spheroidal, ellipsoidal or ribbon-shaped, dense, porous, protoplasmic bodies scattered about in the cytoplasm. Sometimes, as in the cells of lower plants like the Spirogyra, plastids are large and are then called **chromatophores.**

According to the position of the cells in which plastids occur and the work they perform, they differ in color, viz:

Leucoplastids are colorless plastids found in the underground portions of a plant and also in seeds, and other regions given up to the storage of starch. Their function is to build up reserve starch from sugar and other carbohydrates. Leucoplastids may become transformed into chloroplastids upon exposure of cells containing them to light. They are only evident after properly fixing and staining cells containing them.

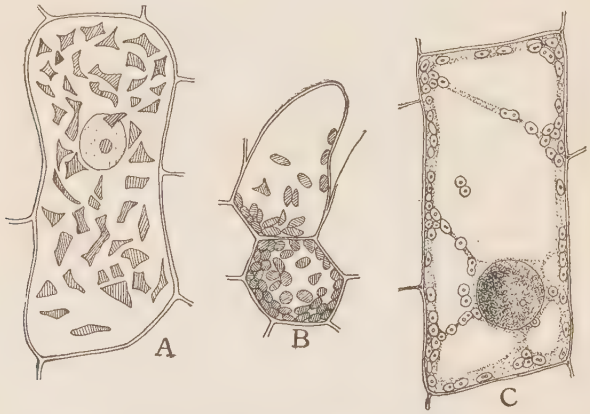

FIG. 36.—A, cell from the epidermis of the upper surface of the calyx of the Nasturtium (*Tropæolum majus*) with crystalline chromoplasts; B, cells from the petal of *Lupinus luteus*, with yellow chromoplasts; C, cell showing numerous chloroplasts scattered through the cytoplasm. A, after Strasburger; B, after Frank. (*Stevens.*)

Chloroplastids are plastids found in cells exposed to light and contain the green pigment, chlorophyll. All green parts of plants contain these bodies. Chloroplastids may develop into chromoplastids, as in the ripening of many green fruits.

Chromoplastids are plastids found in cells independent of their relation to light or darkness and contain a yellow, orange or red pigment called chromophyll.

(*e*) **Cell Membranes.**—These are of three kinds, viz: (1) *The outer plasma membrane* or ectoplasm, found as a transparent, colorless, outer bounding film of cytoplasm enveloping the granular, inner

cytoplasm, the latter sometimes termed "*endoplasm;*" (2) *the vacuolar membranes*, clear bounding films of cytoplasm surrounding sap vacuoles; and (3) *the nuclear membrane*, a clear, transparent film of protoplasm forming the outer bounding zone of the nucleus. All of these membranes are *semipermeable membranes*, since, in their living condition, they will permit the passage through them of water and certain crystalloidal (water-soluble) substances in solution while they will not admit the passage of other crystalloidal susbtances in solution.

(*f*) **Chondriosomes.**—These are small granular or rod-shaped protoplasmic bodies found scattered in the cytoplasm of many cells. They take a deep stain with basic dyes, like chromatin, but their significance is not understood.

CELL FORMATION AND REPRODUCTION

The cells of plants have all been derived from preëxisting cells. In the bacteria and many other low forms of plant life, the division of the cell always results in reproduction; in higher forms, however, it merely increases the size of the individual and so is a phenomenon of growth.

There are two kinds of cells formed by plants, viz.: *asexual* and *sexual*. Both of these are endowed with the possibilities of reproduction, although the former are frequently limited to the process of growth.

Reproduction is the power possessed by an organism of giving rise to new individuals. This may take place through the agency of either asexual or sexual cells and is accordingly asexual or sexual in character. Whenever a union of cells or their protoplasmic contents takes place the process is called "sexual reproduction;" if, however, there is a mere separation of a cell or cells from an individual which later form a new organism, the process is termed "asexual or vegetative reproduction."

There are five modes of **asexual reproduction,** viz.: *Fission, Gemmation, Free Cell Formation, Rejuvenescence* and *Vegetative Multiplication.*

Fission.—This is the separation of a cell into two equal halves, each of which may grow to the size of the original parent cell from

which it was derived. Fission is seen in the reproduction of bacteria, growth of many algæ and the formation of tissues of higher plants.

Gemmation or **Budding.**—This is the method of reproduction common among yeasts. The cell forms a protuberance called a bud which increases in size until it equals the size of the cell which formed it and then becomes detached, although frequently not until it has developed other buds and these still others.

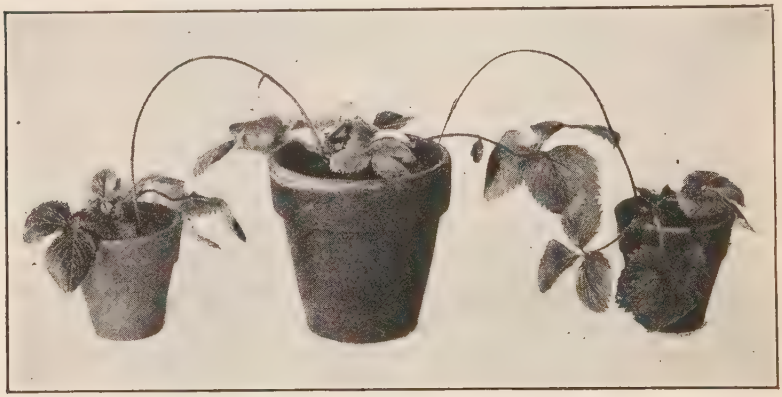

FIG. 37.—Propagation of Strawberry (*Fragaria*) by runners (stolons). The two plants in the small pots developed from the tips of the runners produced by the older plant in the central pot. (*Gager.*)

Free Cell Formation.—This is a type of reproduction in which the nucleus and protoplasm becomes separated into two or more masses each of which forms a cell wall about itself. Seen in formation of ascospores within the ascus of Ascomycetes and spores within spore cases of molds.

Rejuvenescence or **Zoöspore Formation.**—In this mode of reproduction the protoplasm of the cell becomes rounded out, escapes by rupture of the cell wall, forms cilia and moves about as a *zoöspore.* Later it looses its cilia, develops a cell wall and passes into a resting condition. Under favorable circumstances it grows into a new organism. It is found in *Œdogonium*, *Ectocarpus*, etc.

Vegetative Multiplication.—This form of asexual reproduction involves the giving off of multicellular portions or vegetative outgrowths of the parent plant, such as bulbs, tubers and runners, which become detached and develop into new plants. It occurs frequently in nature but is also accomplished artificially through the removal by man of parts of the parent plant, such as stem or root cuttings or, leaves or by layering, *i.e.* bending branches over until they touch the soil and subsequently give off roots and buds, when they are cut away from the parent plant.

There are two kinds of **sexual reproduction,** viz.: *Conjugation* and *Fertilization.* In both of these the sexual cells, called *gametes,* or their nuclei come together and their protoplasm blends to form a new cell. Fertilization is the common method seen in higher plants.

Conjugation.—A union of two gametes, alike in character, the product being a *zygote* or *zygospore.* This method of reproduction is seen in the molds, *Spirogyra, Zygnema,* etc.

Fertilization. —A union of two unlike gametes or their nuclei, the product being an *oöspore.* One gamete, the male sexual cell, is smaller and active, while the other, the female sexual cell, is larger and passive. This process is seen among the higher and many of the lower plants.

INDIRECT NUCLEAR DIVISION (MITOSIS OR KARYOKINESIS)

This is the general method of division seen in the formation of tissues of higher plants.

The process begins in the nucleus and ends with the formation of a cell wall dividing the new-formed cells.

When we examine a cell in its *resting stage,* we find the nucleus more or less spherical in shape, surrounded by a *nuclear membrane* and containing a *nuclear network, nuclear sap* and one or more *nucleoli.* The nuclear network consists of a colorless network of *linin* adhering to which are numerous minute granules called *chromatin* which take the stain of a basic dye. Surrounding the nucleus is the *cytoplasm.*

As the cell commences to divide, the nucleus elongates and the linin threads of the nuclear reticulum shorten, drawing the chro-

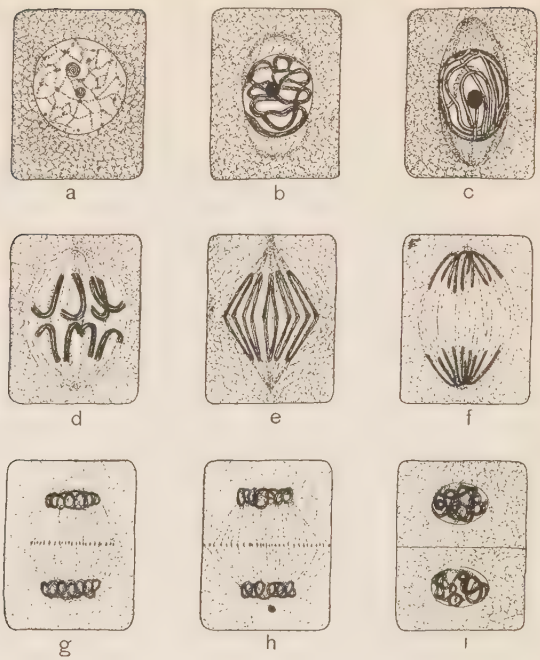

FIG. 38.—Semi-diagrammatic representation of nuclear and cell-division. *a* resting cell ready to begin division; *b*, the nuclear reticulum is assuming the form of a thickened thread, and the cytoplasm at opposite poles is becoming thread-like to form the spindle fibers; *c*, the nuclear thread has divided longitudinally through the middle, and the spindle fibers have become more definite; *d*, the nuclear membrane and the nucleolus have disappeared, and the nuclear thread has become segmented into chromosomes which are assembling at the equator of the cell. All of the phases of division thus far are called *prophases*. *e*, the *metaphase*, where the longitudinal halves of the chromosomes are being drawn apart preparatory to their journey toward the opposite poles; *f*, the *anaphase*, or movement of the chromosomes toward the poles, is about completed, connecting fibers extend from pole to pole; *g*, *telophase* where the chromosomes have begun to spin out in the form of a nuclear reticulum. The connecting fibers have begun to thicken in the equatorial plane; *h*, the connecting fibers have spread out and come into contact with the wall of the mother cell in the equatorial plane, and the thickening of the fibers throughout this plane has made a complete cell plate within which the dividing wall will be produced; *i*, a nuclear membrane has been formed about each daughter nucleus, and the dividing cell-wall is completed. The two daughter cells are now ready to grow to the size of the parent cell in *a*, when the daughter nuclei will appear as does the nucleus there. All highly magnified. (*Stevens.*)

matin granules together into a thickened, twisted, chromatic thread. This thread splits transversely and thus becomes divided into a number of rods termed *chromosomes*. Each of these then splits into two longitudinal halves that may be termed the *daughter-chromosomes*. They lie within the nuclear cavity united by delicate threads. There now begins a phenomenon concerned with the cytoplasm which is primarily a process of spindle formation. The granular cytoplasm accumulates at the poles of the elongated nucleus, forming the *cytoplasmic caps*. Presently it begins to show a fibrillar structure, the threads extending outward around the periphery of the nucleus forming an umbrella-like arrangement of fibers from both cytoplasmic caps. With the formation of fibers comes a breaking down of the nuclear membrane and, in consequence, the fibers enter the nuclear cavity and organize the *spindle*. Some of the fibers become attached to the split chromosomes and push, draw or pull them to the *equatorial plate*, halfway between the poles. Meanwhile the nucleolus disappears. As the chromosomes line up at the *equatorial plate* their daughter halves are drawn apart in V-shaped fashion. The split extends and eventually one daughter-chromosome is drawn to one pole and the remaining half to the other. At the respective poles the daughter chromosomes form a dense compact knot. A cell membrane, composed of material contributed largely through the shrinking of the spindle fibers, is now formed through the middle of the spindle. This soon splits to form a thin vacuole lying between the two membranes (the *plasma membranes*). Presently there appears within the vacuole and between the membranes a carbohydrate substance. On either side of this desposit the plasma membranes form a cellulose membrane. The flattened vacuole extends toward the periphery and ultimately a complete cell wall is formed.

The dense compact knots of chromosomes, at the poles of the spindle, that are to form the daughter-nuclei, now begin to expand and clear mesh-like spaces to appear between the expanding threads. As this process advances the chromosome substance becomes distributed through the nuclear cavity. It is soon possible to distinguish the chromatin from the linin. Eventually an irregular network of linin carrying chromatin granules is formed through the area of the

nucleus. A nuclear membrane also is formed and the nucleolus reappears. The spindle fibers disappear. The daughter-nuclei increase in size and each *daughter-cell* formed by this process now assumes the resting stage.

Number of Chromosomes.—The number of chromosomes found in the cell nucleus varies with the kind of cells considered in each individual and with the species. In all sexually-reproducing plants two kinds of cells occur, the body- or somatic-cells and the germ cells. Each of the body cells contains twice as many chromosomes as each of the germ cells. Thus, the Stramonium contains 24 chromosomes in each of its body cells and 12 in each egg and sperm cell. The number of chromosomes in the body cells is constant and is expressed as $2x$. The number in the germ cells is expressed as x.

REDUCTION DIVISION OR MEIOSIS

Each of the spore mother cells which give rise to pollen grains and to eggs in plants are formed by the division of body cells and like them contain $2x$ chromosomes, of which x chromosomes are contributed by the egg nucleus and x chromosomes by the sperm nucleus. It is apparent that if each uniting egg and sperm had $2x$ chromosomes, the oöspore resulting would contain twice the number of chromosomes as found in the body cells of the parents. Moreover, the body cells of the sporophyte resulting from the division and redivision of the oöspore would contain $4x$ chromosomes. This does not occur, for at a certain stage in the life history of every sexually reproducing plant between each oöspore formation and the next, a reduction division takes place whereby the $2x$ chromosomes are reduced to x chromosomes. This reduction in the chromosome number takes place in the two nuclear divisions of spore mother cells to form pollen grains and embryo sacs with the result that each of the starting points of the gametophyte generation have their chromosomes reduced to the x number.

In the first division called *heterotypic mitosis*, the resultant cells contain, in their two daughter nuclei, only one-half the number of chromosomes found in the nuclei of the body cells. These nuclei do not pass into the resting condition but soon undergo a second division.

In the second division called *homotypic mitosis*, each of the two nuclei divide again to form an aggregation of four daughter cells in all, each with a nucleus containing the x number of chromosomes. The x number of chromosomes continues through the whole gametophyte generation, so that the uniting egg nucleus and sperm nucleus possess this number. In the act of fertilization the x chromosomes from the egg nucleus are combined with the x chromo-

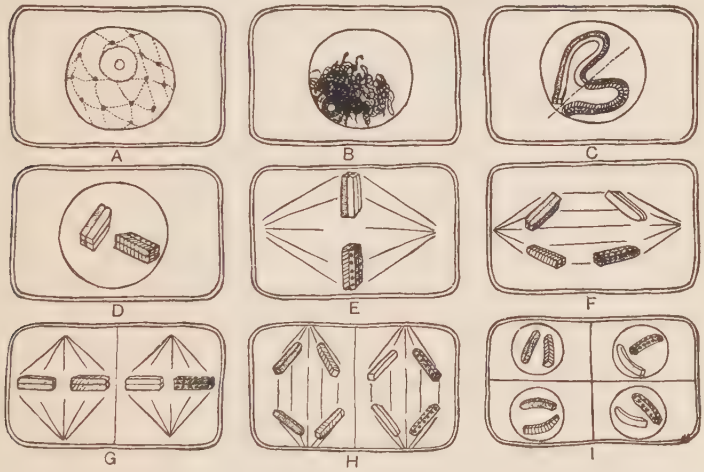

FIG. 39.—Diagram showing various stages in the reduction division of a spore-mother-cell of a plant. A, resting stage of the mother-cell nucleus; B, the nuclear skein or spirem during synapsis; C, the spirem after synapsis, showing its double (diploid) nature; the dotted line indicates the segmentation of the spirem into 2 diploid chromosomes, each of which has split longitudinally in D; E, the diploid chromosomes on the equator of the spindle of the first (heterotypic) division; F, late anaphase; G, metaphase of the second or homotypic division; H, late anaphase of same, two haploid chromosomes approaching the poles of each spindle; I, the four daughter cells (spores) of the tetrad. (*After Gager.*)

somes from the sperm nucleus to form $2x$ chromosomes in the oöspore or zygote. When the oöspore divides, each of its daughter cells contains $2x$ chromosomes and their number is continued throughout the sporophyte generation.

NON-PROTOPLASMIC CELL CONTENTS

1. **Sugars.**—*Sugars* comprise a group of crystalline substances found in the cell sap of many plants either free or in combination

with glucosides. They may be divided into two main groups: monosaccharoses and disaccharoses. To the former belong simple sugars containing two to nine atoms of carbon, which are known respectively as bioses, trioses, tetroses, pentoses, hexoses, etc. Of these the hexoses ($C_6H_{12}O_6$) are the most important and of wide distribution. Examples of the hexoses found in drug plants are: (*a*) dextrose (grape sugar), found in the leaves, stems, fruits, sprouting grains and nectaries of flowers of nearly all plants; (*b*) fructose (levulose or fruit-sugar), commonly associated with dextrose; (*c*) d-mannose, found in the saccharine exudation of the Manna Ash (*Fraxinus Ornus*); and (*d*) sorbinose, found in ripe Mountain Ash berries. Upon evaporating the sap or treating the parts containing these principles with alcohol they can be crystallized out.

Flückiger's Micro-chemic Test for the determination of different kinds of sugars: Dissolve a small portion of copper tartrate in a drop of sodium hydrate on a glass slide; in this place the section and put on the cover slip. If fructose is present cuprous oxide crystals will at once be formed without warming. If grape sugar is also present a gentle warming will produce another crop of reddish-yellow crystals. If dextrin be present continued heating will still further augment the number of crystals. Cane sugar and mannite, on the other hand, will respond negatively to this test. The *zymase* of yeasts is capable of fermenting dextrose, levulose and d-mannose forming carbon dioxide and alcohol. Sorbinose is claimed to be non-fermentable.

The disaccharoses, having the chemical formula of $C_{12}H_{22}O_{11}$, include sucrose, maltose, trehalose, melibiose, touranose and agavose. Of these *sucrose* is the most important. It is found in the stems of sugar cane, sorghum, corn and Mexican grass; in many fleshy roots notably the sugar beet; in the sap of the sugar maple and various palms; in various fruits, as apples, cherries, figs, etc., in the nectaries of certain flowers; in honey; and in a number of seeds. It crystallizes in monoclinic prisms or pyramids. When sections of plant parts containing cane sugar are placed for a few seconds in a saturated solution of copper sulphate, then quickly rinsed in water, transferred to a solution of 1 part of KOH in 1 part of water, and heated to boiling, the cells containing the sugar take on a sky-blue color.

Invertase, an enzyme of the yeast, reduces cane sugar to dextrose and levulose and *zymase,* another enzyme of the same plant, ferments these forming carbon dioxide and alcohol.

Maltose is found in the germinating grains of barley and other cereals as a product of the action of the ferment diastase on starch. It reduces Fehling's solution, forming cuprous oxide, but one-third less with equal weights.

Trehalose or mucose is found in ergot, *Boletus edulis,* the Oriental Trehala and various other fungi.

Melibiose is formed with fructose upon hydrolyzing the trisaccharose melitose which occurs in the molasses of sugar manufacture and in Australian manna.

Touranose is produced upon hydrolyzing melizitose, a trisaccharose which occurs in Persian manna.

Agavose is found in the cell sap of the American Century Plant, *Agave americana.*

2. **Starch.**—Starch is a carbohydrate having the chemical formula of $(C_6H_{10}O_5)_n$ which is generally found as the first visible product of photosynthesis in most green plants. It is found in the chloroplasts and chromatophores of green parts in the form of minute granules. This kind of starch is known as **Assimilation Starch.** Assimilation starch is dissolved during darkness within the chloroplasts by the action of a starch-splitting ferment and passes into water-solution as a glucose which is conveyed downward to those parts of the plant requiring food. In its descent some of it is stored up in medullary-ray cells, and in various parts of the xylem, phlœm, pith and cortex in the form of small grains. Such starch has been termed **Translocation Starch.**

Considerable starch, however, is carried to the underground parts, such as rhizomes, tubers, corms, bulbs or roots, or into aerial storage tissues, as the storage cells of seeds, where the leucoplasts store it in the form of larger-sized grains called **Reserve Starch.** This type of starch is generally characteristic for the plant in which it is found. It constitutes stored-up food for the plant during that period of the year when the vegetative processes are more or less dormant.

Structure and Composition of Starch.—Starch grains vary in shape from spheroidal to oval to conchoidal to polygonal. They

are composed of layers of soluble carbohydrate material and probably other substances called "*lamellæ*," separated from each other by a *colloidal substance* resembling a mucilage in its behavior toward aniline dyes. They contain a more or less distinct highly refractile point of origin or growth called the "*hilum*," which also takes the stain of an aniline dye. The layers of carbohydrate material stain variously, blue, indigo, purple, etc., with different strengths of

FIG. 40.—Cell of *Pellionia Daveauana*, showing reserve starch-grains. The black, crescent-shaped body on the end of each grain is the *leucoplast*. Greatly enlarged. (*Gager.*)

iodine solutions. Each grain is covered with a stainable *elastic membrane.*

Starch grains may be grouped, according to the condition in which they are found in the cells of storage regions into three kinds, viz.: *simple starch grains, compound starch grains and fill starch grains.*

Simple starch grains are such as occur singly. Compound starch grains occur in groups of two, three, four, five, six or more and are designated as two-, three-, four-, five-, six-, etc., compound, according to the number of grains making up the group. Fill starch grains

are small grains filling up the spaces between the larger grains in storage cells. These are common in commercial starches.

Method of Examining Reserve Starches.—Many of the reserve starches are used commercially, such as potato, corn, rice, maranta, oat, wheat, sago, tapioca, etc., and it frequently becomes necessary for the microscopist to determine their purity or their presence in a sample of food or drug. The following characteristics should be noted in determining the identity or source of the starch.

1. The shape of the grain.
2. Whether simple or compound or both; if compound, the number or range in numbers of grains composing it.
3. The size of the grain in microns.
4. The position of the hilum, if distinct; whether central or excentric (outside of the center).
5. The shape of the hilum and the degree to which it is often fissured.
6. The nature of the lamellæ, whether distinct or indistinct; if distinct whether concentric (surrounding the hilum) or eccentric (apparently ending in the margin of the grain and not surrounding the hilum), or both, as in potato starch.
7. The color of the grains when stained with dilute iodine solutions; whether indigo, blue, purple, red or yellowish-red, etc.
8. The appearance under polarized light.
9. The temperature at which the paste is formed.
10. The consistency of the paste.

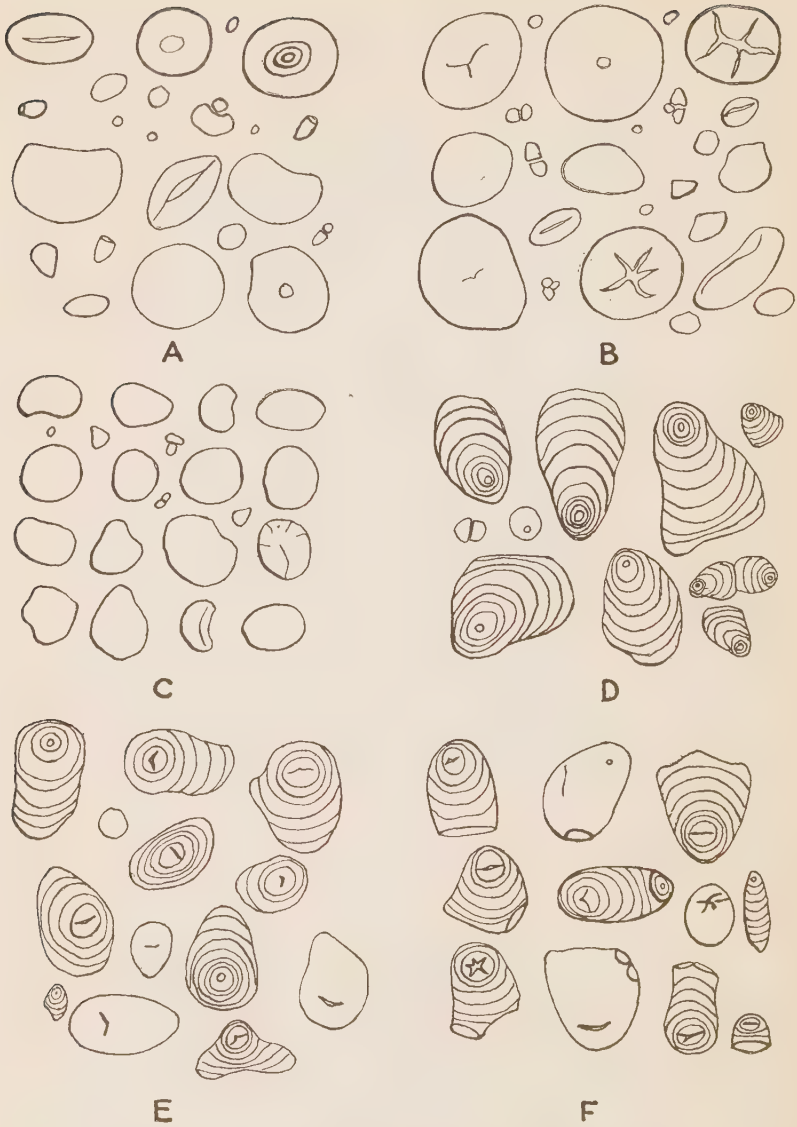

FIG. 41.—A, wheat starch grains; B, rye starch; C, barley starch; D, potato starch; E, Maranta starch; F, Sago starch. Explanation in text.

Characteristics of Important Commercial Starches

Potato Starch (*Solanum tuberosum*)

Mostly simple, conchoidal or ellipsoidal, with occasional spheroidal and two- to three-compound grains.

Size: 5 to 125μ.

Hilum: circular, at smaller end of grain.

Lamellæ: concentric and eccentric.

Polarization cross very distinct; beautiful play of colors with selenite plate.

Maranta Starch (*Maranta arundinacea*)

Ellipsoidal to ovoid.

Simple.

Size: 10 to 65μ.

Hilum: a transverse or crescent-shaped cleft in center or near broad end of grain, or circular.

Lamellæ: usually indistinct.

Polarization cross very distinct; fine play of colors with selenite plate.

Corn Starch (*Zea Mays*)

Polygonal to rounded.

10 to 35μ. Most grains over 15μ in diameter.

Simple.

Hilum: circular or a two- to five-rayed cleft.

Lamellæ: indistinct.

Polarization cross distinct but no marked play of color with selenite plate.

Rice Starch (*Oryza sativa*)

Polygonal.

2 to 10μ in diameter.

Simple or two- to many-compound.

Hilum: usually indistinct, occasionally a central cleft.

Lamellæ: indistinct.

Polarization cross distinct but no play of colors with selenite plate.

Wheat Starch (*Triticum sativum*)

Circular grains appearing lenticular shaped on edge view; simple.

Large grains 28 to 45μ in diameter.

Hilum: central, appearing as dot, but usually indistinct.

Lamellæ: generally indistinct, when present concentric.

Polarization cross indistinct; no play of colors with selenite plate.

Rye Starch (*Secale cereale*)

Grains having a similar shape to those of wheat starch but many larger; simple.

Large grains 20 to 52μ in diameter.

Hilum: a star-shaped central cleft or indistinct in some grains.

Lamellæ: concentric.

Polarization cross distinct.

Barley Starch (*Hordeum distichon*)

Grains having a similar shape to those of wheat starch but frequently tending to bulge on one side and so appear sub-reniform; large grains smaller; simple.

Grains appear elliptical to lemon shaped in edge view. Large grains usually 18 to 25μ, occasionally up to 30μ in length.

Hilum: centric or circular or cleft, often indistinct.

Lamellæ: concentric, often indistinct.

Polarization cross distinct.

Buckwheat Starch (*Fagopyrum esculentum*)

Grains simple and compound.

Simple grains polygonal or rounded-polygonal.

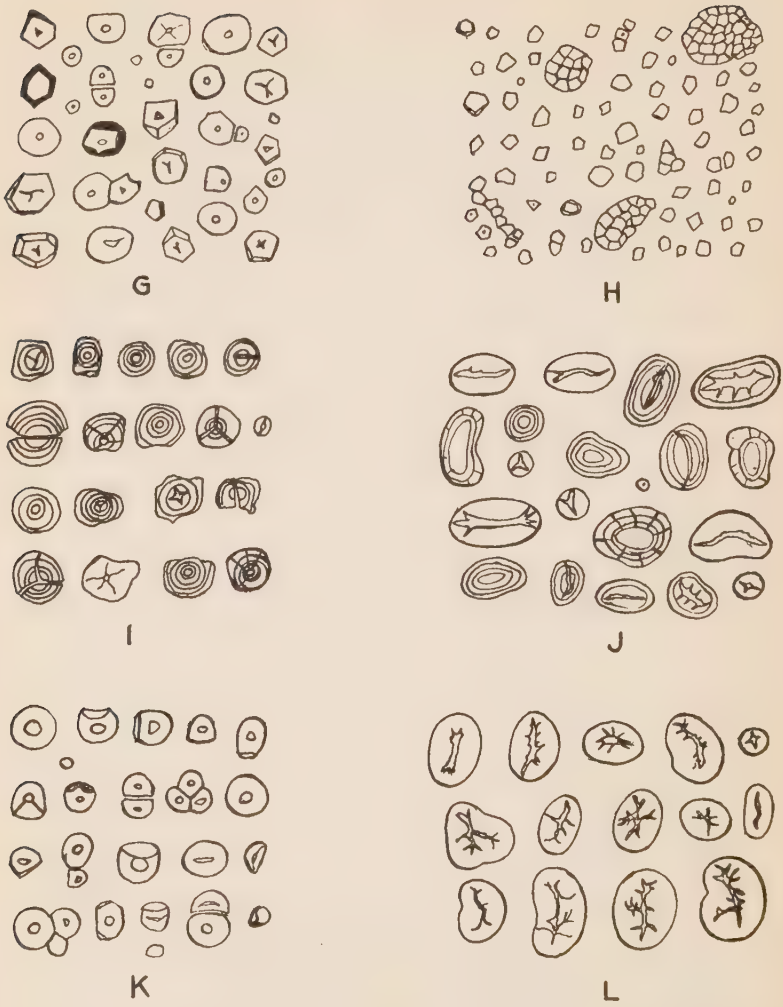

FIG. 42.—G, corn starch; H, rice starch; I, corn dextrin; J, pea starch; K, cassava starch; L, bean starch. Explanation in text.

Buckwheat Starch

Compound grains more or less rod-shaped.
2 to 15μ in diameter.
Hilum: central.
Lamellæ: generally indistinct.
Polarization cross distinct.

Cassava Starch (*Manihot utilissima*)

Grains rounded, truncated on one side.
Simple or two- to three- or four- to eight-compound.
6 to 35μ in diameter.
Hilum: central, circular or triangular with radiating clefts frequently.
Lamellæ: indistinct.
Polarization cross prominent.

Bean Starch (*Phaseolus vulgaris*)

Ovoid, ellipsoidal or reniform shaped simple grains, occasionally obscurely 3- or 4-sided.
25 to 60μ in length. Generally from 30–35μ.
Hilum: central, elongated with branching clefts.
Lamellæ: distinct, concentric. In some indistinct.
Polarization crosses shaped thus, χ.

Pea Starch (*Pisum sativum*)

Oval-oblong, elliptical or sub-reniform.
15–51μ in length. Generally from 20–40μ.
Hilum: similar to that of bean starch but less cleft or simply elongated.
Lamellæ: distinct, concentric.
Polarization crosses similar to bean starch.

Canna Starch (*Canna edulis and other species of Canna*)

Broadly elliptical, flattened, with beak or obtuse angle at one end.
50 to 135μ in length.
Hilum: excentric near narrower end.
Lamellæ: concentric and eccentric.
Polarization cross very distinct; fine play of colors with selenite plate.

Sago Starch (*Metroxylon Sagu*)

Ovoid, muller-shaped, or irregularly 3 or 4 sided with rounded angles. Some more or less gelatinised.
Simple or 2, 3 or 4-compound.
30–60μ long.
Hilum: excentric, often altered by gelatinisation.
Lamellæ: eccentric and concentric.
Polarization cross distinct.

3. **Dextrin.**—Dextrin is a carbohydrate made from starch (chiefly from corn or potato starch) by the application of heat (yellow dextrin) or by treatment with both heat and acids (white dextrin). It forms a paste with water, the yellow variety tending to swell up and dissolve much more readily than the white. When examined microscopically in alcohol mounts, the grains, while conforming in general outline to those of the type of starch from which the dextrin was prepared, nevertheless show more conspicuous striations and clefts. Corn dextrin shows distinct striations, whereas striations in corn starch are absent. The grains take on a red coloration with iodine solutions.

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4. **Amylodextrin.**—This is a carbohydrate intermediate in properties between starch and dextrin. It occurs in the form of small, irregularly shaped granules, in Mace, that take on a reddish brown to reddish violet color with iodine solutions.

5. **Inulin.**—Inulin is a carbohydrate isomeric with starch which has the chemical formula of $C_{12}H_{20}O_{10}$. It is found dissolved in the cell sap of many plants, especially those of the *Compositæ*. If pieces of a plant part containing this substance be placed directly in alcohol for at least a week, then sectioned and mounted in alcohol, sphæro-crystals of inulin will be seen applied to the walls of the cells. When

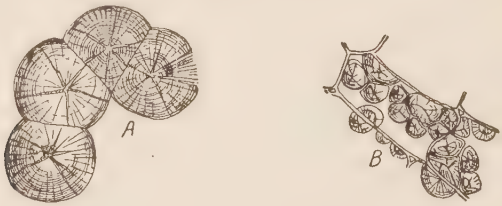

FIG. 43.—Inulin, in the form of sphæro-crystals from the tuber of *Dahlia*. *A*, precipitated from an aqueous solution; *B*, precipitated within the cells by long standing in alcohol. (*From Stevens, after Sachs.*)

these sections are treated with a 10 per cent. solution of alpha naphthol in alcohol and 2 or 3 drops of strong H_2SO_4, the sphæro-crystals will dissolve with a violet color. Fehling's solution is not reduced by inulin.

6. **Glucosides.**—These substances are very numerous in the plant kingdom. They arise in the cell sap of plants containing them as products of constructive metabolism (anabolism) and are thought by many to have the function of protecting plants against the ravages of animals. Some are known to serve as reserve food. All glucosides are characterized by the property of being split up into glucose and other substances when acted upon by a ferment, dilute acids or alkalies.

Examples of Glucosides

Hesperidin.—Hesperidin is a glucoside having the chemical formula of $C_{21}H_{26}O_{12}$. Like inulin it occurs in solution within the cell sap. It is found in abundance in the Rutaceæ family but occurs

in many other plants. If sections of alcoholic material containing this substance, such as Buchu leaves or unripe orange peel, are mounted in alcohol and examined, sphærocrystals will be seen. If these are then treated with a drop of alpha naphthol solution and 2 or 3 drops of strong H_2SO_4, they dissolve with a yellow color. The same coloration is evident when 5 per cent. solution of KOH is substituted for the alpha naphthol and H_2SO_4.

Strophanthin.—This is a glucoside occurring in the cell sap of the endosperm of *Strophanthus Kombe*, *S. hispidus* and other species of *Strophanthus*. If sections of fresh Strophanthus seeds are mounted in a drop of water and then transferred to a drop of concentrated H_2SO_4, the cells containing strophanthin will assume a bright green color.

Salicin.—Salicin is a glucoside occurring in the cell sap of the bark and leaves of the Willows and Poplars. Sections of these mounted in concentrated H_2SO_4 will show a red coloration in the cells containing this substance. If water be added, a red powder is thrown down.

Saponins are glucosides which have the property of frothing with water. They are found in Soap Bark, Senega, Saponaria, Yucca and other drugs and take a red color with strong H_2SO_4.

Coniferin is a glucoside, occurring in the cell sap of the spruce, pine, and other plants of the *Coniferæ*. If sections containing it are first treated with a solution of phenol and then with sulphuric acid, the cells containing it take on a deep blue color.

Digitoxin, a glucoside found in the leaves of *Digitalis purpurea*, is colored green with hydrochloric acid.

Cyanogenetic glucosides are common in the seeds of the Rose and Legume families. They yield hydrocyanic acid when hydrolyzed by enzymes or other agents.

7. **Pentosides.**—These are substances related chemically to glucosides, differing from the latter in yielding pentose as one of the products, when decomposed (hydrolyzed) by enzymes, dilute acids, etc. The aloins found in the juices of various species of *Aloe* are examples of these principles. One of these, "barbaloin," found in the official Aloe gives a greenish fluoresence in aqueous solutions, when the latter are saturated with borax.

8. **Alkaloids.**—Chemically, these are basic carbonaceous amines which like glucosides are products of metabolism. Their method of formation in plants is uncertain. Some hold that they are katabolic products, resulting from the breaking down of tissues, while others believe them anabolic in character. They undoubtedly serve as defensive agents in plants containing them on account of their bitter taste and poisonous properties.

Properties of Alkaloids

Alkaloids are invariably found in combination with acids forming salts which dissolve in water or alcohol. They are composed of carbon, hydrogen and nitrogen. Some contain oxygen. They are precipitated from saline solutions by the addition of alkalies. They are mostly colorless and crystallizable. They can be precipitated by one or more of the following alkaloidal reagents: tannic acid, gold chloride, phospho-molybdic acid, picric acid and potassio-mercuric iodide.

Examples of Alkaloids

Strychnine.—This alkaloid, with a chemical formula of $C_{21}H_{22}N_2O_2$, occurs in the seeds of *Strychnos Nux-vomica*, *Strychnos Ignatii* and other species of *Strychnos*. When sections of strychnine containing seeds, previously treated with petroleum ether and absolute alcohol, are mounted in a solution of 1 Gm. ammonium vanadate in 100 cc. of sulphuric acid, they take on a violet-red color which later changes to brown.

Nicotine.—This is a volatile alkaloid having the formula of $C_{10}H_{14}N_2$ which is found in the *Nicotiana* genus of the Nightshade family. Sections of tobacco leaves or stems mounted in dilute Lugol's solution will show first a carmine-red color and then a reddish-brown precipitate which in time loses its color.

Caffeine.—This alkaloid, with a formula of $C_8H_{10}N_4O_2 + H_2O$, occurs in Tea, Coffee, Maté or Paraguay Tea, leaves of *Ilex vomitoria* or Yaupon, and seeds of Kola, Cocoa, etc. If thin sections containing it are placed on a glass slide in 2 or 3 drops of concentrated hydrochloric acid and gently heated and then 2 or 3 drops of gold

chloride solution are added, the sections then pushed to the side and the liquid allowed to evaporate, slender, yellowish, branching needles of caffeine gold chloride will be seen to separate.

Cocaine.—This narcotic alkaloid, having the formula $C_{17}H_{21}NO_4$, is found in the leaves of *Erythroxylon Coca* and *E. Truxillense*. If sections of these leaves are prepared in the same manner as indicated for those containing Caffeine, but platinum chloride solution substituted for that of gold chloride, large feathers or plumes of cocaine-chloro-platinate will be seen separating.

Aconitine ($C_{33}H_{43}NO_{12}$) is found in various parts of *Aconitum Napellus*. It is particularly abundant in the tuberous root of this plant. If sections of aconite root are treated on a glass slide with solution of potassium permanganate, a red precipitate of aconitine permanganate will appear in the cells containing this alkaloid.

Colchicine ($C_{22}H_{25}NO_6$).—This alkaloid occurs in the corm and seeds of *Colchicum autumnale*. It is very abundant in the cells surrounding the fibro-vascular bundles of the corm. If a section of either corm or seed be treated with a mixture of 1 part of H_2SO_4 and 3 parts of H_2O, the cells containing colchicine will be colored yellow. If a crystal of KNO_3 then be added, the color will change to a brownish-violet.

9. **Gluco-alkaloids.**—These are compounds intermediate in nature between alkaloids and glucosides, having characteristics of each. To this group belongs solanine ($C_{28}N_{47}NO_{11}$) which is found in *Solanum nigrum, Solanum Dulcamara, Solanum carolinense* and other species of the *Solanaceæ*. When sections of those plant parts which contain this constituent are mounted in a solution of 1 part of ammonium vanadate in 1000 parts of a mixture of 49 parts of sulphuric acid with 18 parts of water, the cells containing solanin take on a yellow color which changes successively to orange, various shades of red, blue-violet, grayish-blue and then disappears.

10. **Asparagine** ($C_4H_8N_2 + H_2O$).—This is an amino compound of crystalline nature which occurs widely in the plant kingdom. It has been found in certain of the slime molds and fungi, in the roots of *Althæa officinalis* and *Atropa belladonna*, in young shoots of *Asparagus*, in the seeds of *Castanea dentata*, in the tubers of *Solanum tuberosum* and varieties of *Dahlia*, and is known to play an important

part in metabolism. Stevens claims that proteids are reduced for the most part to asparagine during seed germination.[1] If thick sections are cut from a plant part containing this substance and

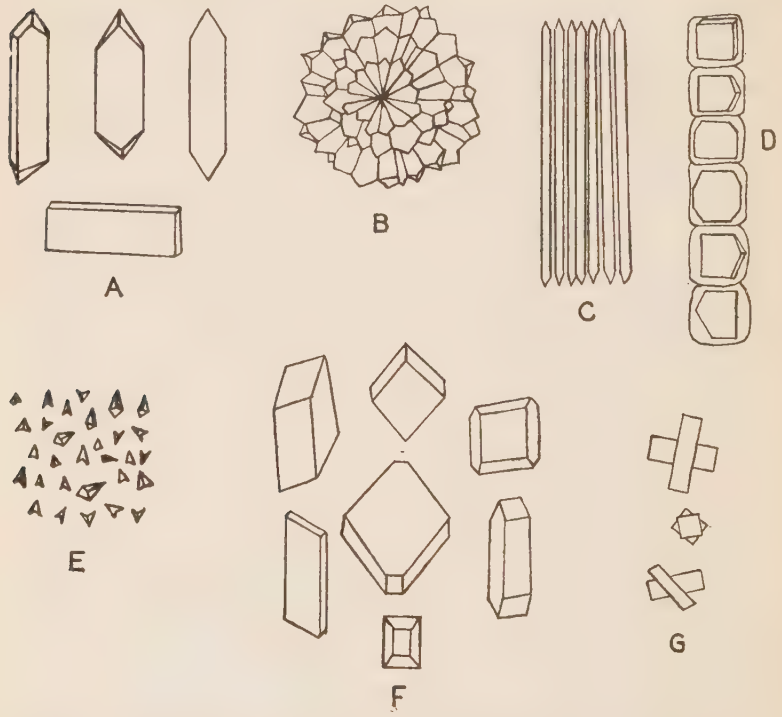

FIG. 44.—Various forms of calcium oxalate crystals. A, styloids from the bark of *Quillaja saponaria;* B, rosette aggregate from rhizome of *Rhcum officinale;* C, raphide from the bulb of *Urginea maritima;* D, crystal fiber as seen in longitudinal section in either the xylem or phloem regions of *Glycyrrhiza;* E, microcrystals (crystal sand) isolated from the parenchyma of *Belladonna* root; F, monoclinic prisms; and G, twin-crystals from leaves of *Hyoscyamus niger.* All highly magnified.

mounted in alcohol, rhombohedral crystals of asparagin in the form of plates will be deposited upon the evaporation of the alcohol. If to these a few drops of a saturated solution of asparagine are added the crystals already formed will increase in size. To get satisfactory

[1] Stevens' Plant Anatomy, 3d Edit., p. 189.

results the saturated solution must be of the same temperature as the mount.

11. **Calcium Oxalate.**—This substance occurs in many plants always in the form of crystals. It is apparently formed by the reaction of salts of calcium, which have found their way into the cell sap from the soil, with oxalic acid which is manufactured by the plant. Calcium oxalate crystals dissolve readily in mineral acids without effervescence. They are insoluble in acetic acid or water. These crystals are classified according to form and belong either to the monoclinic or tetragonal system.

Crystals belonging to the monoclinic system possess 3 axes of unequal length, two of which are obliquely inclined to each other, the other axis forming right angles with these two. They appear to be more frequently found in plants than those of the tetragonal system.

Crystals belonging to the tetragonal system have 3 axes at right angles to each other; two of the axes are equal in length, the third being of a different length.

Crystals belonging to the Monoclinic System and Examples of Drugs Containing Them:

1. Solitary—Hyoscyamus, Acer Spicatum, Viburnum Prunifolium.

2. Rosette Aggregates—Althæa, Gossypii Cortex, Stramonium, Granatum, Rheum, Fœniculum, Viburnum, Eucalyptus.

3. Columnar (Styloids)—Quillaja, Iris.

4. Raphides—Convallaria, Sarsaparilla, Veratrum Viride, Scilla, Phytolacca, Ipecacuanha, Hydrangea.

5. Micro-crystals (Crystal sand)—Belladonnæ Radix, Cinchona, Stramonium, Phytolacca, Capsicum. This type is frequent in the Solanaceæ family.

6. Crystal Fibers—Cascara Sagrada, Prunus Virginiana, Glycyrrhiza, Aspidosperma, Senna.

7. Membrane Crystals—Aurantii Dulcis Cortex, Limonis Cortex, other Citrus peels, Condurango.

Solitary crystals, usually in the form of rhombohedra, occasionally in twin crystals, occur as sharp angular bodies, each one often completely filling up the lumen of a cell.

Rosette aggregates consist of numerous small prisms or pyramids, or hemihedral crystals arranged around a central axis, appearing like a rosette or star.

Columnar crystals or styloids are elongated prisms.

Raphides are groups of acicular or needle-shaped crystals, which occur in long, thin-walled cells containing mucilage. They are more frequently found in Monocotyledons than in any other plant group.

Micro-crystals (sphenoidal micro-crystals or crystal sand) are minute arrow-shaped or deltoid forms completely filling the parenchyma cells in which they occur and giving these a grayish-black appearance.

Crystal fibers are longitudinal rows of superimposed parenchyma cells each of which contains a single monoclinic prism or rosette

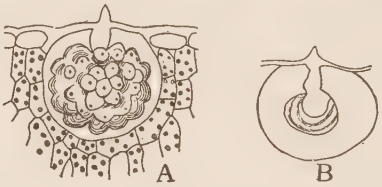

FIG. 45.—Cystoliths from the leaf of the Fig (*Ficus carica*). *A*, Cystolith within cystolith sac; *B*, cystolith from which the calcium carbonate has been removed for use in other parts of the plant. *B* is from leaf that has fallen off in autumn. (*From Stevens after Haberlandt.*)

aggregate. Crystal fibers are found adjacent to sclerenchyma fibers such as bast or woody fibers.

Membrane crystals are monoclinic prisms, each of which is surrounded by a wall or membrane. In the process of formation, a crystal first is formed in the cell sap and then numerous oil globules make their appearance in the protoplasm surrounding it; later some of the walls of the cell grow around the crystal and completely envelop it.

12. **Cystoliths.**—Cystoliths are clustered bodies formed by the thickening of the cell wall at a certain point and subsequent ingrowth which latter forms a cellulose skeleton consisting of a stalk and body. Silica is subsequently deposited on the stalk while calcium carbonate is piled up on the body in layers, forming an irregular spheroidal or ellipsoidal deposit. These structures are

abundantly found in the plants of the Nettle Family and constitute a leading peculiarity of the same (see Fig. 45).

Hair cystoliths differ from the average type in that they are devoid of a stalk. Such are seen in the non-glandular hairs of *Cannabis sativa*.

The calcium carbonate incrustation of a cystolith dissolves with effervescence on the addition of a mineral or organic acid.

13. **Silica.**—Silica (SiO_2) occurs in a number of plants either as an incrustation in the cell wall, as in Diatoms, the *Equisetineæ* and *Gramineæ* or more rarely in the form "silica bodies," such as are found in certain Palms and Orchids. It is insoluble in all the acids except hydrofluoric. It may be obtained in pure form by placing tissue containing it in a drop or two of concentrated sulphuric acid and after a time treating with successively stronger solutions of chromic acid (starting with 25 per cent.) and then washing with water and alcohol.

14. **Tannins.**—Tannins are amorphous substances occurring in plants having an astringent taste, and turning dark blue or green with iron salts. They occur in greatest quantity in the bark of exogens, and in gall formations. They are soluble in water, alcohol, glycerine, and a mixture of alcohol and ether. They are almost insoluble in absolute ether and chloroform. They give insoluble precipitates with organic bases such as alkaloids and with most of the salts of the heavy metals.

According to their behavior with solution of iron chloride or other soluble iron salts, two kinds of tannic acid are recognized: (*a*) a form of tannic acid giving a bluish-black color, as that which is found in Rhus, Castanea, Granatum, Galla, etc.; (*b*) another tannic acid producing a dark green coloration, as that found in Krameria, Kino, Mangrove bark, Quercus, Catechu, etc.

If sections are placed in a 7 per cent. solution of copper acetate for a week or more, then placed on a slide in 0.5 per cent. aqueous solution of ferric chloride, and after a while washed with water and mounted in glycerin, an insoluble brownish precipitate will be produced in those cells containing tannin.

Braemer's reagent (Sodium tungstate 1 Gm. and Sodium acetate 2 Gm. dissolved in 10 cc. of water) is superior to solutions of iron

salts in the detection of tannin, since some other plant constituents give a dark-green or bluish-black color with iron. It gives a yellowish-brown precipitate.

15. **Proteins.**—Proteins are complex nitrogenous substances forming the most important of the reserve foods of plants. They are found in all the living and many of the dead cells of plants, although most abundant in seeds. Protoplasm, itself, is composed largely of these substances. They all contain carbon, hydrogen, oxygen, nitrogen and sulphur, and many contain in addition phosphorus. They are formed by the addition of nitrogen, sulphur and frequently phosphorus to elements of grape sugar. The nitrogen, sulphur and phosphorous elements are obtained from nitrates, sulphates and phosphates which are dissolved in the water taken in through the roots. The names of proteins recorded may be found by the hundreds. These are grouped into chemical classes, the most important of which from the standpoint of their occurrence in plants are the *globulins*, *albumens*, *glutelins*, *nucleins*, and *gliadins*. Of these the *globulins* are found most extensively. Globulins are insoluble in water but soluble in sodium chloride solutions. They do not coagulate upon the application of heat.

Albumens are soluble in water and coagulate with heat.

Glutelins are insoluble in water, sodium chloride solution and strong alcohol.

Gliadins are nearly or wholly insoluble in water but soluble in 70 to 90 per cent. alcohol.

Nucleins are insoluble in water but soluble in alkaline solutions.

The following tests are of value in determining the presence of proteins.

Lugol's solution (made by dissolving 5 Gm. of iodine and 10 Gm. of potassium iodide in enough water to make product weigh 100 Gm.) stains proteins yellow or brown.

Concentrated nitric acid stains proteins yellow. This color becomes deeper upon the addition of ammonia water.

Milon's reagent (made by dissolving 3 cc. of mercury in 27 cc. of fuming nitric acid without heat and adding an equal volume of distilled water) stains proteins a brick-red.

Concentrated solution of nickel sulphate colors proteins yellow or blue.

If sections are placed for an hour or two in a solution of 1 Gm. of sodium phospho-molybdate in 90 Gm. of distilled water and 5 Gm. of nitric acid, the proteid substances appear as yellowish granules.

The *globulins* (phytoglobulins) frequently occur in bodies called "aleurone grains."

ALEURONE GRAINS

Aleurone grains are small bodies found in seeds particularly those containing oil, and like starch grains often are characteristic of the genus or species. Each aleurone grain consists of a ground substance (composed of amorphous proteid matter soluble in water, dilute alkali or acid), in which are usually embedded one or more *phyto-globulins* (insoluble in cold water, but soluble in less than 1 per cent. solution of an alkali, in dilute HCl and acetic acid), one or more transparent, globular *globoids* composed of Ca and Mg phosphate (insoluble in water and dilute potash solution but soluble in 1 per cent. acetic acid solution), and frequently a crystal of *calcium oxalate*, the whole being enclosed by a *protoplasmic membrane* (soluble in water). (Fig. 46*B*.)

The proteins insoluble in the cell-sap water are made soluble for translocation by means of *proteolytic enzymes* which change them into proteoses and peptones.

16. **Mucilages and gums** are those substances occurring in plants which are soluble in water or swell in it, and which are precipitated by alcohol.

Mucilage is formed in plants in several ways, viz.; either as a product of the protoplasm, as a disorganization product of some of the carbohydrates, as a secondary thickening or addition to the cell wall, or as a metamorphosis of it. In the first two cases the mucilage is called *cell-content mucilage;* in the last two, *membrane mucilage*.

Mucilage is stored as reserve food in the tubers of Salep and many other Orchids and also in the seeds of some species of the *Leguminosæ*.

Cell-content mucilage has been found in the leaves of Alœ, the rhizomes of Triticum, the bulb scales of Squill and Onion and

in certain cells of many other Monocotyledons, especially those containing raphides.

Membrane mucilage has been observed in *Barosma*, *Ulmus*, *Althæa*, *Linum*, *Astragalus*, and *Acacia* species, in the Blue-green Algæ, and many of the Brown and Red Algæ.

When mucilage is collected in the form of an exudate from shrubs and trees it constitutes what is termed a *gum*. Many of these gums are used in pharmacy, medicine and the arts. The three most important from a pharmaceutical standpoint are: **Acacia,** yielded by *Acacia Senegal* and other species of *Acacia;* **Tragacanth,** yielded by

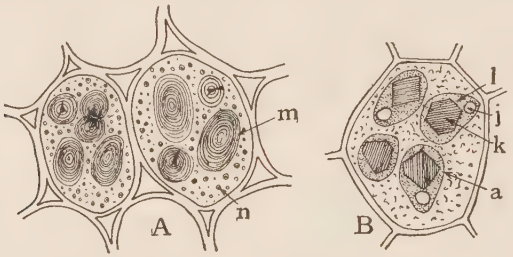

Fig. 46.—To show aleurone grains. *A*, cells from cotyledon of seed of garden bean; *n*, aleurone grains; *m*, starch; *B*, cells from endosperm of castor bean; *a*, aleurone grain; *l*, ground substance; *k*, phytoglobulin; *i*, globoid. (*A*, *After Sachs; B, after Frank.*)

Astragalus gummifer and other Asiatic species of *Astragalus;* and **Cherry Gum,** obtained from *Prunus Cerasus* and its varieties.

Mucilage may be demonstrated in plant tissues containing it by placing sections of these in a deep blue solution of methylene-blue in equal parts of alcohol, glycerin and water on a glass slide, allowing them to remain in the solution for several minutes, then draining off the stain and mounting in glycerin. Those cells containing mucilage will exhibit bluish contents.

17. **Fixed Oils and Fats.**—These are fatty acid-esters of glycerin which are found in the vacuoles of cells or formed with the cell walls from which they may be liberated as globules upon treating sections with chloral hydrate or sulphuric acid or heating them. They are quite soluble in ether, chloroform, benzol, acetone and volatile oils but insoluble in water, and, with the exception of castor

oil, insoluble in alcohol. They are readily distinguished from the volatile oils in that they leave a greasy stain upon paper which does not disappear. Fixed oils and fats take a brownish to black color with osmic acid, a red color with alkannin or Sudan III and a blue color with cyanin. In Vaucheria, the Diatoms and a few of the other Thallophytes, fixed oil is formed in the chromatophores instead of starch as the first visible product of photosynthesis. In higher plants it is generally found in storage regions, such as the parenchyma of seeds, fruits and the medullary-ray cells and parenchyma of barks, roots and rhizomes.

18. **Volatile Oils.**—These are volatile odoriferous principles found in various parts of numerous plants which arise either as a direct product of the protoplasm or through a decomposition of a layer of the cell wall which Tschirch designates a "resinogenous layer." They are readily distilled from plants, together with watery vapor, are slightly soluble in water, but very soluble in fixed oils, ether, chloroform, glacial acetic acid, naphtha, alcohol, benzin and benzol. They leave a spot on paper which, however, soon disappears. They respond to osmic acid, alkannin, Sudan III, and cyanin stains similar to the fixed oils and fats.

Volatile oils may be grouped into four classes:

A. **Pinenes** or **Terpenes,** containing carbon and hydrogen and having the formula of $C_{10}H_{16}$. Examples: Oil of Turpentine and various other volatile oils occurring in coniferous plants.

B. **Oxygenated oils,** containing carbon, hydrogen and oxygen. Examples: Oil of cassia and other cinnamons.

C. **Nitrogenated oils,** containing carbon, hydrogen and oxygen with nitrogen (from HCN). Example: Oil of Bitter Almonds.

D. **Sulphurated oils,** containing carbon, hydrogen and sulphur. Example: Volatile oil of mustard.

19. **Resins, Oleoresins, Gum Resins, and Balsams.**—These substances represent products of metabolism in many plants which are formed either normally, as Turpentine, Asafœtida, Mastiche, etc., or as a result of pathological processes through injury to the plant tissues, as Styrax, Benzoin, Balsam of Tolu and Peru, etc. They occur usually in special cavities such as secretion cells, glands, or secretion reservoirs.

Resins are insoluble in water but mostly soluble in alcohol. They combine with alkalies to form soap. Many of them are oxidized oils of plants. Examples: Guaiacum, Resina, Mastiche.

Oleoresins are mixtures of oil and resin. Examples: Terebinthina, Terebinthina Canadensis, Terebinthina Laricis, Copaiba.

Gum resins are natrual compounds of resin, gum and oil. Examples: Asafœtida, Myrrha, Cambogia.

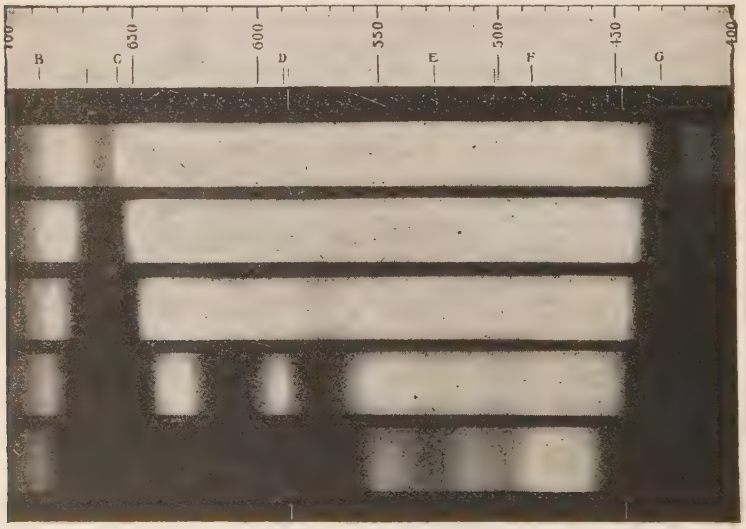

FIG. 47.—Absorption spectra of five different concentrations of chlorophyll *a*. The strongest is represented by the lowest spectrum. (*From Palladin after Willstätter and Stoll.*)

Balsams are mixtures of resins with cinnamic or benzoic acid or both and generally a volatile oil. Examples: Tolu, Styrax, Balsamum Peruvianum.

If sections of a resin-containing plant part are placed in a saturated aqueous solution of copper acetate for a week or two and mounted in dilute glycerin, the resin will be stained an emerald green.

20. **Pigments.**—These are substances which give color to various plant parts in which they are found. They occur either in special protoplasmic structures, as chloroplasts, chromoplasts or chroma-

tophores, or dissolved in the cell sap. Of the pigments named the following will be considered: Chlorophyll, Xanthophyll, Chromophyll, Carotin, Etiolin, Anthocyanin, Phycocyanin, Phycophæin, and Phycoerythrin.

Chlorophyll is a collective name given to the two green pigments found in the chloroplastids or chromatophores of leaves or other green parts of plants. Its composition is not definitely known although it yields products similar to the hæmoglobin of the blood

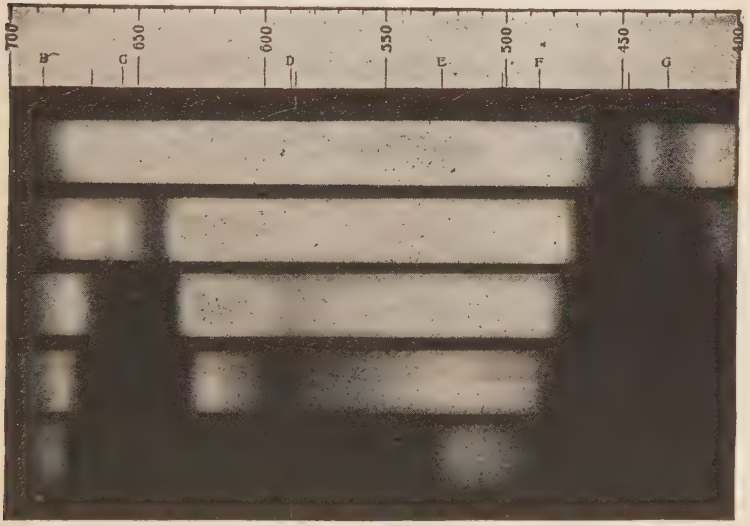

FIG. 48.—Absorption spectrum of five different concentrations of chlorophyll *b*. The strongest is represented by the lowest spectrum. (*From Palladin after Willstätter and Stoll.*)

when decomposed. Iron is known to be essential to its formation and Magnesium, Carbon, Hydrogen, Oxygen and Nitrogen are components of it. If green leaves be boiled in water to kill the plasma membranes, the water poured off, strong alcohol added and the leaf material allowed to macerate in the alcohol for some time, an alcoholic extract of the green leaves can be obtained. If a portion of this alcoholic extract of green leaf be diluted with water to an 85 per cent. alcoholic solution and xylene or benzine be gradually added

and the mixture shaken, the pigments in solution will break up into a yellowish and a greenish portion. The greenish portion dissolves in the xylene, which rises, forming the upper stratum, while the yellowish portion dissolves in the alcohol and water forming the lower stratum. By repeatedly shaking and adding alcohol to the greenish fraction it can be entirely separated from the yellowish fraction. The isolated greenish portion of alcoholic leaf extract has been found to consist of two green pigments called *chlorophyll a* and *chlorophyll b*. When separated and dissolved in alcohol, *chlorophyll a* appears blue-green and *chlorophyll b*, yellowish-green in transmitted light. By reflected light, the former is blood-red, the latter brownish-red. *Chlorophyll a* constitutes 72 per cent. by weight of the green pigments and has, as so far known, the formula of $C_{55}H_{72}O_5N_4Mg$. *Chlorophyll b* represents the remaining 28 per cent. and has, as far as is known, the formula of $C_{55}H_{70}O_6N_4Mg$. The isolated yellowish portion of the leaf extract consists of two pigments, *carotin* and *xanthophyll*.

Alcoholic solution of chlorophyll, when examined spectroscopically in several concentrations, shows absorption bands in the red, orange, yellow and green with a diffuse band in the violet-blue zone of the spectrum, the sharpest band being in the red.

Chromophyll is a broad term applied to either the yellow or orange pigments found in chromoplastids. Sulphuric acid forms a blue color with chromophyll.

Carotin is an orange to orange-red pigment which has the chemical formula of $C_{40}H_{56}$. It is found accompanying the chlorophyll within chloroplasts, but exists separately in chromoplastids of leaves, flowers, fruits and seeds, as well as subterranean parts of higher plants. It is especially abundant in the roots of carrots. It is readily soluble in chloroform, ether and carbon bisulphide, slightly soluble in hot alcohol and insoluble in water. When examined with a spectroscope, it shows two dark bands in the green-blue half of the spectrum.

Xanthophyll is a yellow pigment which accompanies the chlorophyll in the chloroplast. Chemically it represents an oxidation product of carotin, having the formula of $C_{40}H_{56}O_2$.

Etiolin is a pale yellow pigment which appears when green plants are kept for some time in darkness. It is probably identical with xanthophyll.

Anthocyanins are applied to the blue, purple and red pigments which occur in the cell sap of floral organs, stems, leaves, roots and fruits. The character of the color is claimed to be due to the alkalinity or acidity of the cell sap.

Phycocyanin is the blue pigment found in the blue-green algæ, associated with chlorophyll. It is soluble in water and glycerin but insoluble in ether and alcohol.

Phycophæin is the brown pigment found in the brown algæ. It is readily soluble in water.

Phycoerythrin is the red pigment found in many of the red algæ. It is readily soluble in water but insoluble in ether and alcohol.

The last two pigments are always associated with chlorophyll but frequently conceal it.

21. **Latex.**—This is an emulsion of varying composition and color found in special passages, as latex cells and laticiferous vessels, of many plants. It may contain starch, sugar, proteid, oil, enzymes, bitter principles, tannins, alkaloids, gum, resins, caoutchouc and mineral salts. The color may be absent, as in *Oleander;* whitish as in *Asclepias*, *Papaver*, *Hevea*, and *Apocynum;* yellowish to orange, as in *Celandine,* or red, as in *Sanguinaria.*

Chlor-zinc-iodine solution imparts to latex a wine-red color.

The latex of the following plants is of value to pharmacy and the arts:

Papaver somniferum and its variety *album* which yields **Opium.** That from the unripe capsules is alone used for this drug.

Palaquium Gutta and *Payena* sp. which yields **Gutta Percha.**

Hevea species, *Ficus elastica*, *Landolphia* species, *Castilloa elastica*, *Hancornia speciosa*, *Forsteronia* species, *Funtumia elastica* and *F. africana*, *Manihot* species, *Clitandra* species and various species of *Euphorbia* furnish most of the **Rubber** of commerce.

Lactuca virosa and other species of *Lactuca* yield the drug **Lactucarium.**

22. **Enzymes.**—An *enzyme* or soluble *ferment* or unorganized ferment (according to Hepburn) is a soluble organic compound of

biologic origin functioning as a thermolabile (sensitive to heat) catalyst in solution. Ostwald has defined a catalyst as an agent which alters the rate of a reaction without itself entering into the final product, or which does not appear to take any immediate part in the reaction, remains unaltered at the end of the reaction and can be recovered again from the reaction product unaltered in quantity and quality. The biologic catalysts (enzymes) differ from the inorganic catalysts in that they are sensitive to heat and light. According to Haas and Hill they are destroyed at 100°C. and most of them cannot be heated safely above 60°C. Enzymes are soluble in water, glycerin or dilute saline solutions. They are stimulated to activity by substances known as "*activators*" and their activity is checked by other substances called "*paralyzers*." Frequently the paralyzers consist of products of enzyme action. Cold inhibits and warmth accelerates enzyme action. Moisture must always be present for enzymic activity.

CLASSIFICATION OF ENZYMES

A. According to Diffusibility through Cell Wall.

Endocellular: Those that cannot diffuse out of the cell. Example: Zymase of Yeast.

Extracellular: Those that can diffuse out of the cell. Example: Invertase of Yeast.

B. According to Kind of Substances Acted upon and Transformed.

1. **Carbohydrate Enzymes:**

Diastase, found in the germinating seeds of barley and other grains and in *Aspergillus oryzæ,* etc., converts starch to maltose and dextrin.

Invertase, secreted by yeasts, and found in younger parts of higher plants, transforms cane sugar, producing dextrose and levulose.

Maltase, found in malt, in green leaves, and *Saccharomyces octosporus,* transforms maltose to dextrose.

Trehalase, found in *Polyporus,* hydrolyzes trehalose to dextrose.

Cytase, found in Nux Vomica and Ignatia seeds, in barley, dates, etc., decomposes hemicellulose and cellulose to galactose and mannose.

Lactase, found in Kephir grains, hydrolyzes lactose to dextrose and galactose.

Pectinase, found in fruits and other plant organs, transforms the pectates of the middle lamella into arabinose.

Inulase, found in plants of the Daisy and Bluebell families, etc., transforms inulin to levulose.

Zymase, found in yeast, hydrolyzes glucose (dextrose and levulose) to alcohol and carbon dioxide.

2. **Fat and Oil Enzyme:**

Lipase splits up fats and oils into fatty acids and glycerin. It is found in various mildews, molds and numerous oily seeds and other fatty-oil storage regions of higher plants.

3. **Proteinaceous Enzymes:**

Pepsin converts proteids into proteoses and peptones.

Trypsin, found in yeast, *Boletus edulis*, *Amanita* species, etc., resolves proteins to peptones and amino-acids.

Bromelin, found in the fruit of the Pineapple, and **Papayin** (Papain), found in the latex of the fruit of the Papaw, act similarly to trypsin.

Nepenthin, found in the pitchers of *Nepenthes* species, acts similarly to pepsin.

4. **Glucoside Enzymes:**

Emulsin (synaptase), found in the seeds of the Bitter Almond, Cherry Laurel leaves, in the barks of the Wild Black Cherry and Choke Cherry and in other Rosaceous plant parts, in *Manihot utilissima*, *Polygala* species, etc., hydrolyzes the glucoside present (either amygdalin or l-mandelonitrile glucoside) to hydrocyanic acid, benzaldehyde and glucose.

Myrosin (myronase), found in the seeds of *Brassica nigra* and other members of the *Cruciferæ*, converts the glucoside, Sinigrin, into allyl-iso-sulphocyanide and glucose.

Rhamnase, found in *Rhamnus Frangula* and probably other species of *Rhamnus*, hydrolyzes the glucoside frangulin to rhamnose and emodin.

Gaultherase, found in *Gaultheria procumbens* and other Ericaceous plants, resolves the glucoside, gaultherin, to methyl-salicylate and glucose.

6. **Organic Acid Enzymes:**

Reductase of yeast decomposes lactic acid to pyrotartaric acid and hydrogen. It also decomposes formic acid into carbon dioxide and hydrogen.

Carboxylase, found in higher plants, splits pyrotartaric acid into acetic aldehyde and carbon dioxide.

C. Oxidizing Enzymes.

These are enzymes which absorb molecular oxygen from the air and combine it with plant constituents.

Oxidases are common in plants and are responsible for discolorations seen in the tissues of many barks and fruits when they are bruised or broken and exposed to the air. The juices and extracts of plants containing oxidases turn brown upon exposure to air.

CELL WALLS

The cell walls of plants make up the plant skeleton. They are all formed by the living contents of the cells (protoplasts) during cell-divisions. In most plants the cell wall when first formed consists of *cellulose*, $(C_6H_{10}O_5)_n$, a carbohydrate, or closely allied substances. It may remain of such composition or become modified to meet certain functions required of it. Thus, in the case of outer covering cells as epidermis and cork, whose function is that of protecting the underlying plant units, the walls become infiltrated with *cutin* (in the case of epidermal cells), *suberin* (in the case of cork cells), waxy-like substances, which make them impermeable to water and gases, as well as protect them against easy crushing. Again, in the case of stone cells and sclerenchyma fibers whose function is that of giving strength and support to the regions wherein found, the walls become infiltrated with *lignin* which increases their strength, hardness, and in the case of sclerenchyma fibers, their elasticity also. Moreover, in the case of the cells comprising the testa or outer seed coat of the pumpkin, squash, mustard, flax, etc., whose function is that of imbibing quantities of water, the walls undergo a *mucilaginous modification.* These, upon the imbibition of water, swell up and form layers of mucilage within the cell cavities.

The sub-epidermal cells beneath the upper epidermis of Buchu leaves exhibit a striking example of *mucilaginous modification of*

cellulose as to their walls. If transverse sections of either fresh or dried Buchu leaf-blades are first mounted in strong alcohol and observed under the microscope, the walls of the sub-epidermal cells appear no different from ordinary cellulose walls; if, however, the alcohol be gradually withdrawn from beneath the cover slip and gradually replaced with water, these walls will be seen to swell and form layers of mucilage in the cell lumina. The mucilage formed absorbs water so rapidly that, in a relatively short time, the pressure (turgor) within the cells becomes so great as to cause a rupture of the less elastic vertical walls of the sub-epidermis with a consequent separation of the upper epidermal cells from those of the palisade layer beneath and the appearance of a broad rent in the section.

Growth in Area and Thickness.—The cell wall when first formed is limited in both extent and thickness. As the protoplast within enlarges, new particles are placed within the wall by the process called *intussusception*. This increases its area. New particles, also, are deposited on its surface which gradually increases its thickness. The latter process is known as *growth by apposition*.

VARIOUS KINDS OF CELL WALLS AND BEHAVIOR OF EACH TO MICROCHEMIC REAGENTS

Nature of wall	*Where found*	*Reagent and behavior toward same*
Cellulose.....	Parenchyma cells, trichomes such as cotton, etc.	Cuoxam dissolves it. Chlorzinc-iodine solution imparts a blue or violet color. Iodine solution followed by sulphuric acid colors it blue.
Lignocellulose (Lignified wall).	Woody parts of plants, such as stem cells, bast fibers, wood fibers, etc.	Phloroglucin with HCl imparts a red color except to bast fibers of flax and ginger. Corallin-soda solution imparts a pink color. Aniline sulphate with H_2SO_4 colors it a golden-yellow. Chlorzinc-iodine imparts a yellow color.
Reserve cellulose.	Found in certain seeds such as nux vomica, ignatia, ivory nut, date, coffee, etc.	As for cellulose.
Mucilaginous modification of cellulose.	In various parts of plants.	Alcoholic or glycerin solution of methylene-blue imparts a blue color.
Suberized walls...	In cork, wounded areas of plants, endodermis.	Alcoholic extract of chlorophyll, in the dark, imparts a green color. Alcannin and Sudan III impart a red coloration. Converted into yellowish droplets and granular masses upon heating with a strong solution of KOH. Sulphuric acid is resisted.
Cutinized walls...	Forming outer walls of many epidermal cells.	As for suberized walls.
Callus of sieve plates.	Plates of sieve tubes.	Corallin-soda solution imparts pink color.
Silicified walls....	Epidermis of Horsetails, Grasses, etc.; Diatoms.	Soluble in hydrofluoric acid.

CHAPTER VII

PLANT TISSUES

A **tissue** is an aggregation of cells of common source, structure and function in intimate union.

THE TISSUES OF SPERMATOPHYTES AND PTERIDOPHYTES

The tissues of seed plants and pteridophytes are all derived from a fertilized egg (oöspore) which has undergone repeated divisions. At first either an apical cell arises (pteridophytes) or a mass of cells is formed (spermatophytes) at the tips of growing regions which are essentially alike and constitute the *primordial meristem;* but gradually we find that a division of labor has become operative setting aside many different groups of cells, each group of which has its particular rôle to perform in the economy of the whole. Each group of cells similar in source, structure and function is called a tissue. The tissues found in higher plants range from those whose component cells are more or less rounded, in a rapid state of division, and whose thin, cellulose, cell walls enclose a mass of protoplasm, devoid of vacuoles, or with exceeding small ones to those whose cells through various physical and chemical factors become compressed, elongated, and highly modified in respect to their contents and walls.

The adult or permanent tissues represent those which have been laid down by the cell-division of meristems. They include two general classes depending on the character of the cell components. That class of permanent tissues whose cells are thin-walled and more or less box-shaped is called **parenchyma** and its cells are termed **parenchymatous.** That class which includes all those permanent tissues whose cells are fibrous or vessel-like in form is called **prosenchyma** and its cells are termed **prosenchymatous.**

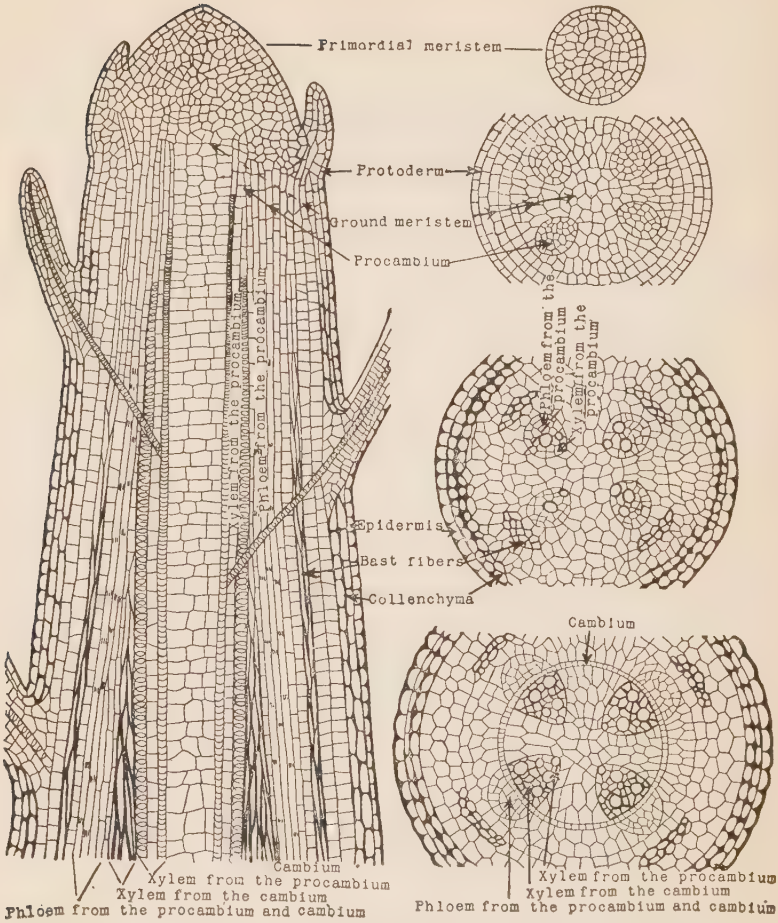

FIG. 49.—Diagram showing the evolution of tissues in a stem from the primordial meristem down to the beginning of cambial activity. In the longitudinal diagram, at the bottom, the initial C of the word cambium stands directly beneath this tissue which is radially but one cell in thickness. (*After Stevens.*)

As was shown by Hanstein,[1] the embryo of Angiosperms, while still constituted of only a few cells in the process of division, becomes differentiated into three layers of cells which differ in their arrangement and direction of division; these were called by him *Dermatogen*, *Periblem* and *Plerome*. In roots a fourth layer of cells is sometimes evident at the apex. This was termed by Janczewski[2] the *Calyptrogen* layer. These primary layers or groups of cells are called *primary meristems* or *generative tissues*. They are composed of more or less rounded cells having delicate cell walls of cellulose which enclose protoplasm and nucleus, and wherever found in living embryos are in a rapid state of division.

The generative tissues are found in the growing apices of plant organs, such as root, stem and leaf apex. By the division and redivisions of their cells they give rise to the mature or adult tissues of plants.

1. **Dermatogen** or **protoderm** originates epidermal tissue and derivative structures such as stomata, non-glandular and glandular hairs, glands, and sometimes cork cambium.

2. **Periblem** or **ground meristem** originates primary cortex tissue, chlorophylloid cells (chlorenchyma), colloid cells (collenchyma), strengthening cells (sclerenchyma), crystal cells (raphiderchyma), latex cells (lacterchyma), pericycle, endodermis, sometimes cork cambium and pith.

3. **Plerome** or **procambium** originates the primary or first fibrovascular bundles, and the cambium.

According to the structure of the component cells and their location, the following tissues are found in various forms of higher plants:

1. **Meristem**
2. **Parenchyma**
3. **Collenchyma**
4. **Sclerenchyma**
5. **Epidermis**
6. **Endodermis**
7. **Pericycle**
8. **Cork**
9. **Laticiferous tissue**
10. **Sieve or cribiform tissue**
11. **Tracheary tissue**
12. **Medullary rays**

[1] Hanstein, "Die Scheitelzellgruppe im Vegetationspunkt der Phanerogamen," Bonn, 1868.

[2] Am. Sci. Nat. 5 série, tom. xx.

MERISTEM

Meristem, frequently called embryonic tissue, is undifferentiated tissue composed of cells in the state of rapid division. It is found in the growing apices of roots, stems and leaves and is in these regions called **primordial meristem,** since it is the first meristem to appear. The primordial meristem gives rise through cell divisions to the **primary meristems** which in turn develop the primary permanent tissues of plants. Primary meristems retain the power of independent growth and capacity for division as long as the plant part survives which contains them. Meristem is also found in other regions of plant organs such as the cambium, cork cambium and pericambium and is there called **secondary meristem.** Secondary meristem is a derivative of primary meristem. It gives rise to the secondary permanent tissues. It loses with its transition the power of division and independent growth.

PARENCHYMA

Parenchyma or **Fundamental Tissue** is the soft tissue of plants, consisting of cells about equal in length, breadth and thickness (isodiametric) with thin cellulose cell walls enclosing protoplasm and a nucleus and frequently substances of a non-protoplasmic nature. There are four generally recognized types of parenchyma, viz.:

Ordinary Parenchyma (**Soft Ground Tissue, Fundamental Tissue**).—Next to the meristem this is the least modified of all plant tissues. It is generally composed of thin-walled cells, commonly polyhedral or spheroidal in form and often of approximately the same length, breadth, and thickness (isodiametric); the cell walls are composed of cellulose which is usually unmodified. Occasionally the outline of the cells is star-shaped or stellate, as in the stems of Wood Rush or Pickerel Weed or the cells may be several times as long as wide, as in the stems of Geranium, etc. Moreover, markings may occur on the walls. These may be of the nature of pores, as in the parenchyma cells of the pith of the Elder or Sassafras, annular as in the Mistletoe, or spiral thickenings, as in certain Orchids. Protoplasm and a nucleus are always present, but in old cells are

only seen as a thin layer pushed up against the cell wall. Ordinary Parenchyma may be seen composing the soft tissues of roots, stems, and barks.

Assimilation Parenchyma (Chlorophyll or Chromophyll Parenchyma, Chlorenchyma).—This form of parenchyma tissue is found in foliage leaves, floral leaves, in the outer region of young green stems and fruits. Its cells are thin-walled and vary in shape from more or less isodiametric to irregular and elongated forms. The cells always contain chloroplasts or plastids, in whose pores may be found some other coloring substance. Good examples of assimilation tissue are seen in the green column-shaped cells below the upper epidermis of foliage leaves which, because of their shape, are termed "*palisade parenchyma cells*" and in the green rounded to irregular-shaped cells beneath the palisade parenchyma of foliage leaves which, because they are more loosely arranged around air-spaces, are termed "*spongy parenchyma cells.*"

Conducting Parenchyma.—This type of parenchyma functions in the rapid translocation of food materials to distant regions in the plant. It includes the *wood parenchyma cells* of the *xylem* which convey a portion of the crude sap (water with mineral salts in solution) and the *phloem parenchyma* (soft bast) which transports the elaborated sap (carbohydrate and proteid material in solution). Conducting parenchyma cells differ from those of ordinary parenchyma in being usually more elongated and in conducting soluble food materials with greater celerity.

Reserve Parenchyma.—This resembles ordinary parenchyma in many particulars of structure but differs from it mainly by its cells being filled with starch, protein crystals, or oil globules. It is usually found in seeds, fleshy roots, or underground stems such as tubers, corms, and bulbs.

Collenchyma.—This form of tissue is characterized by its cells being prismatic, more elongated than ordinary parenchyma, and thickened in their angles with a colloidal substance. The cells, like those of parenchyma tissue, contain protoplasm and a nucleus, and frequently chloroplasts (Fig. 50). Collenchyma is generally found underneath the epidermis, and gives strength to that tissue. It is the first strengthening tissue to develop in stems. It is frequently

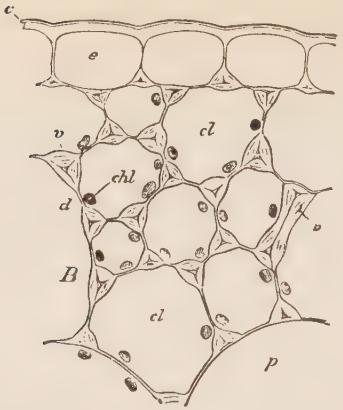

FIG. 50.—Transverse section of part of leaf-stalk of a begonia. *e*, Epidermis; *c*, cuticle; *B*, collenchyma, with walls thickened at the angles, *v*; *chl*, chloroplasts (*Sayre after Vines.*)

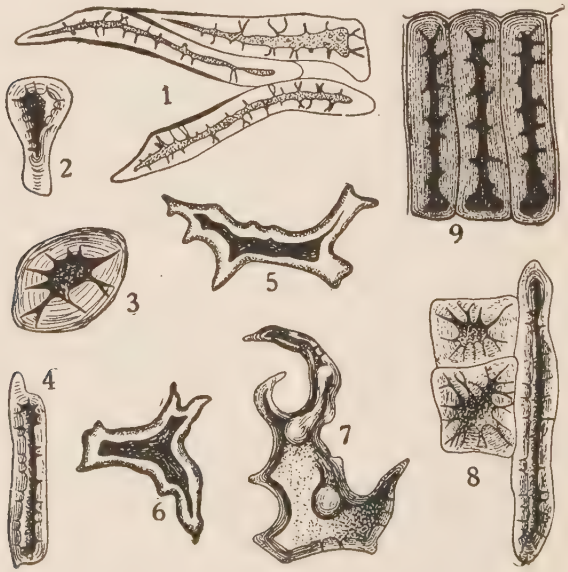

FIG. 51.—Stone cells from different sources. 1, From coffee; 2, 3, and 4 from stem of clove; 5 and 6, from tea leaf; 7, 8 and 9, from powdered star-anise seed. (*Stevens, after Moeller.*)

observed forming the "ribs" of stems and fruits of the Parsley Family and "ribs" of stems of the Mint Family. In many leaves it

FIG. 52.—Stone cells from various sources. 1, From olive pit; 2, from cocoanut endocarp; 3, from flesh of pear; 4, from aconite root; 5, from capsicum; 6, from hazelnut; 7, from allspice. (*Drawing by Hoffstein.*)

has been found as the supporting and strengthening tissue between the stronger veins and the epidermis.

Sclerenchyma or stony tissue comprises a variety of supporting elements having thickened cell walls composed of lignocellulose. When first formed these cells resemble those of ordinary parenchyma in having walls of pure cellulose, but later *lignin*, a hard, woody substance, becomes deposited on the inner surface of the walls in one or

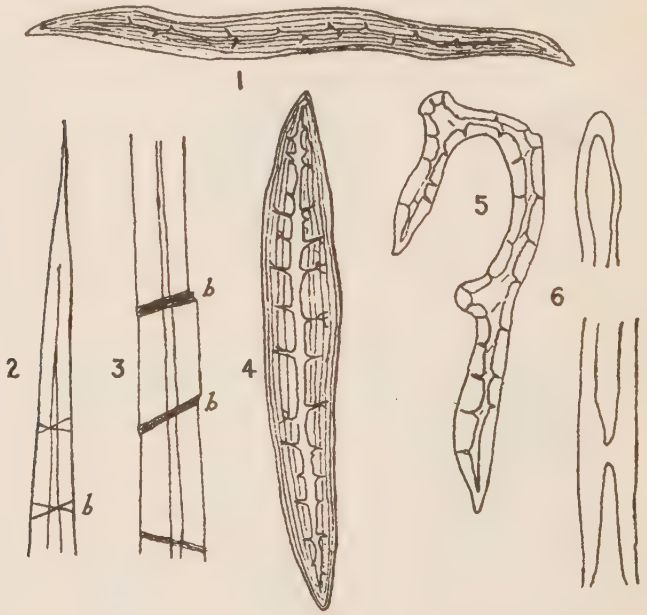

FIG. 53.—Sclerenchyma fibers from different sources. 1, From powdered cinnamon bark; 2, end of bast fiber of flax stem showing transverse markings (*b*); 3, middle portion of flax fiber showing characteristic cross markings at *b*; 4, bast fiber from cinchona bark; 5, branched bast fiber from choke cherry bark; 6, above, end, and below, median portion of bast fiber of jute. All highly magnified.

more layers. (Occasionally, as in the rhizomes of Ginger, no lignin is deposited on the walls of the sclerenchyma fibers.) When sclerenchyma is composed of cells which are more or less isodiametric or moderately elongated, with thickened, lignified walls and conspicuous pores, its elements are called **Stone Cells.** Stone cells are distributed in fruits, seeds and barks of many plants, rarely in woods. They have been found forming the gritty particles in the

"flesh" of certain fruits as the Pear, the endocarp or stone region of drupaceous fruits as the Olive, Peach, Cubeb, Pepper, etc., the hard portions of seed coats as in Physostigma, Walnuts, etc. Each stone cell presents for examination a cell wall of cellulose with one or several layers of lignin on its inner surface which surround a *central lumen.* The latter is in communication with radial *pore canals* leading outward to the middle lamella. Longitudinal pore canals are also evident.

When sclerenchyma is composed of cells which are greatly elongated and more or less obtusely or taper ended, its component elements are termed **Sclerenchyma fibers.** These fibers are frequently spindle-shaped, contain air and exhibit oblique slits in their walls. They are either polygonal, rectangular or somewhat rounded in transverse section. They occur in various parts of roots, stems, leaves, fruits and seeds as supporting elements. When sclerenchyma fibers occur in the xylem region of fibro-vascular bundles, they are termed *Wood Fibers* or *Libriform Tissue;* when they appear in the phloem region, *Bast Fibers* or *Liber Fibers;* when in the pericycle, *Pericyclic Fibers.* Wood fibers are usually cut off by the cambium only and so are generally seen in the secondary xylem. They are averagely shorter than the bast fibers in the same plant axis.

EPIDERMIS

Epidermis is the outer covering tissue of a plant and is protective in function. Its cells may be brick-shaped, polygonal, equilateral or wavy in outline. Their outer walls are frequently *cutinized* (infiltrated with a waxy-like substance called cutin). Among the epidermal cells of leaves and young green stems may be found numerous pores or *stomata* (sing. *stoma*) surrounded by pairs of crescent-shaped cells, called guard cells. The stomata are in direct communication with air chambers beneath them which in turn are in communication with intercellular spaces of the tissue beneath. The function of the stomata is to give off watery vapor and take in or give off carbon dioxide, water and oxygen. In addition to stomata some leaves possess groups of *water stomata* which differ from *transpiration stomata* in that they always remain open, are circular in outline, give off water in droplets directly, and lie over an area of

small, secreting, glandular cells (*epithem*) which is in connection with a bundle of tracheids that springs from the ends of one or more

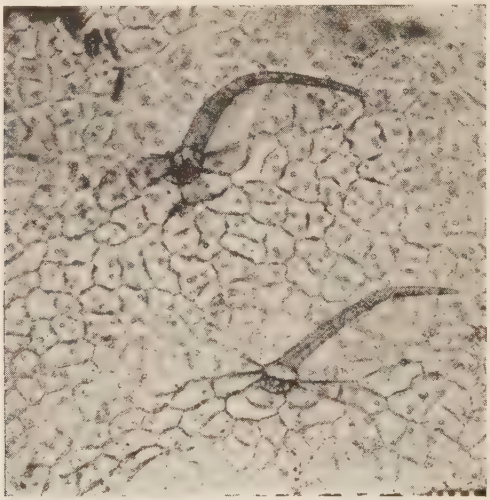

FIG. 54.—Upper epidermis of Sweet Fern (*Comptonia asplenifolia*) leaf (surface view) showing epidermal cells and two non-glandular trichomes.

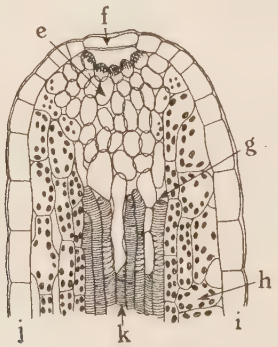

FIG. 55.—Radial-longitudinal section through a hydathode from the leaf margin of *Primula sinensis*. *i*, upper, and *j*, lower epidermis; *h*, palisade cell; *e*, thin walled parenchyma called epithem; *g*, intercellular space; *f*, guard cell of a water stoma; *k*, tracheids. (*From Stevens, after Haberlandt.*)

fibro-vascular bundles. An air chamber usually occurs directly beneath the water pore. Haberlandt gave the name of *hydathode* to

FIG. 56.—Trichomes from different sources. 1, Unicellular non-glandular trichomes as seen growing out of epidermal cells of *Senna;* 2, uniseriate non-glandular trichomes of *Digitalis;* 3, unicellular stellate trichomes from *Deutzia scabra;* 4, unicellular twisted trichomes from lower epidermis of *Eriodictyon;* 5, clavate non-glandular trichomes from scraping of epidermis of the fruits of *Rhus glabra;* 6, 2-branched trichomes of *Hyoscyamus muticus,* a substitute for Henbane; 7, branched multicellular trichome of *Marrubium;* 8, glandular trichomes from strobile of *Humulus* (Lupulin); 9, glandular trichomes from leaves of *Digitalis purpurea;* 10, aggregate, non-glandular trichomes of *Kamala;* 11, lateral view (to left) and vertical view (to right) of glandular trichomes of *Kamala;* 12, vertical view (above) and profile view (below) of 8-celled glandular hair from *Mentha piperita.* All highly magnified.

this and related types of structures which secrete water in the form of droplets. Examples: Leaves of Primula, Corn, various grasses, Potato, Elm, Larkspur, *Crassula*, *Saxifraga* and *Ficus*.

The epidermis of leaves, stems, fruits, and seeds of many plants frequently gives rise to outgrowths in the form of papillæ, hairs and

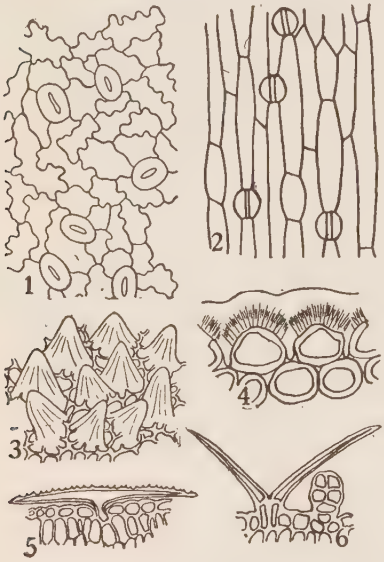

Fig. 57.

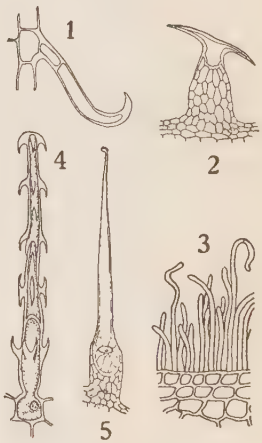

Fig. 58.

Fig. 57.—1, Epidermis of oak leaf; 2, epidermis of Iris leaf, both viewed from the surface; 3, group of cells from petal of Viola tricolor, showing conical papillæ; 4, two epidermal cells in cross-section showing thickened outer wall differentiated into three layers, namely, an outer cuticle, cutinized layer (shaded), and an inner cellulose layer; 5 and 6, epidermal outgrowths in the form of scales and hairs. (1, 2, 6 *after Stevens*, 3 *after Strasburger*, 4 *after Sachs, and* 5 *after de Bary.*)

Fig. 58.—Different forms of epidermal outgrowths. 1, Hooked hair from *Phaseolus multiflorus;* 2, climbing hair from stem of *Humulus Lupulus;* 3, rod-like wax coating from the stem of *Saccharum officinarum;* 4, climbing hair of *Loasa hispida;* 5, stinging hair of *Urtica urens.* (*Fig.* 3. *after de Bary; the remainder from Haberlandt.*)

scales. *Epidermal papillæ* are short protuberances of epidermal cells. They may be seen to advantage on the upper epidermis of the ligulate corolla of various species of *Chrysanthemum*, on the lower epidermis of the foliage leaves of species of *Erythroxylon* and upon

the upper epidermis of the petals of the Pansy (*Viola tricolor*). **Epidermal hairs** or **trichomes** are more elongated outgrowths of one or more epidermal cells. They may be unicellular (Cotton) or multicellular, non-glandular (simple) or glandular. The *non-glandular* hairs may be of various shapes, viz.: clavate (club-shaped) as on *Rhus glabra* fruits; stellate (or star-shaped) as on *Deutzia* leaves; candelabra-shaped, as on Mullein leaves; filiform, as on Hyoscyamus, Belladonna and Digitalis leaves; hooked, as on the stems of the Scarlet Runner Bean or Hops; barbed, as on the stems of *Loasa* species; or tufted, as found on the leaves of Horehound (*Marrubium vulgare*). They may be simple as in Cotton, etc., or branched as in *Hyoscyamus muticus*.

The *glandular hairs* comprise those whose terminal cell or cells are modified into a more or less globular gland for gummy, resinous or oily deposits. They are generally composed of a stalk and a head region although rarely the stalk may be absent. The stalk may be unicellular, bicellular, uniseriate (consisting of a single series of superimposed cells) or multiseriate (consisting of two or more rows of superimposed cells). The head varies from a one- to many-celled structure. The drug *Lupulin* consists of the glandular hairs separated from the strobiles of the Hop (*Humulus lupulus*).

Scales are flat outgrowths of the epidermis composed of one or several layers of cells. They occur attached to the stipes of *Aspidium*, *Osmunda* and other ferns, where they are called "chaff scales." They are also found on a number of higher plants.

Functions of Hairs.—Plant hairs are adapted to many different purposes. They may absorb nourishment in the form of moisture and mineral matter in solution, *e.g.*, root hairs. Those which serve as a protection to the plant may be barbed and silicified, rendering them unfit for animal food, or, as in the nettle, charged with an irritating fluid, penetrating the skin when touched, injecting the poison into the wound. A dense covering of hairs also prevents the ravages of insects and the clogging of the stomata by an accumulation of dust. They fill an important office in the dispersion of seeds and fruits, as with their aid such seeds as those of the milkweed and Apocynum are readily scattered by the wind.

The reproductive organs of many Cryptogams are modified hairs, as the sporangia of Ferns.

ENDODERMIS

Endodermis is the "starch sheath" layer of cells, constituting the innermost layer of the cortex. In Angiospermous stems it usually resembles the other parenchyma layers of cortex as to structural characteristics, save that it frequently contains more starch. In fern stems, roots of Monocotyledons and of Dicotyledons of primary growth, however, its cells are clearly distinguished from the other cells of the primary cortex by their elongated form and suberized (occasionally lignified) radial walls. In the roots of Mexican Sarsaparilla the inner as well as the radial walls are suberized; in those of the Honduras variety, inner, radial and outer walls all show suberization. Endodermal tissue is devoid of intercellular-air-spaces. Its cells contain protoplasm and nucleus. Its functions seem to be to give protection to the *stele* (tissues within it) and to reduce permeability between primary cortex and stele.

CORK

Cork or suberous tissue is a protective tissue composed of cells of tabular shape, whose walls possess a layer of water-proof substance called *suberin*. It is formed by the division of the cells of the *phellogen* or cork cambium which cuts off cork cells outwardly. Its cells, when first formed, contain protoplasm and nucleus but, as the cork cambium forms new layers of cork on its exterior, the older cork cells lose their protoplasmic contents, die, become filled with air or a yellowish or brownish substance, and gradually sluff off. Under the microscope, dead cork cells usually appear black due to air filling their cavities. Thin sections of cork, when mounted in suitable reagents, will show that the walls of the cork cells are composed of three layers or lamellæ. The lamella next to the cell cavity is cellulose. Outside of this is a middle lamella which may be lignified and a lamella of suberin. Cork tissue is usually devoid of intercellular-air-spaces. It forms a protective covering to the roots of secondary growth, perennial stems (after the first season)

of Dicotyledons and Gymnosperms, and wounds of stems and branches. It protects the delicate underlying tissues from invasion by fungal parasites, from sudden changes in temperature, and from loss of water.

The suberized walls of cork cells resist the action of concentrated sulphuric acid. They are colored green, when in contact with alcoholic extract of chlorophyll for several days in the dark.

Borke is a term which has been applied by German botanists to designate the dead tissues which sluff off when cork cambium arises and forms layers of cork in deep regions of the cortex and in the pericycle. This occurs in the oak, birch, grape vine, elm, etc.

PERICYCLE

The **pericycle** or **pericambium,** as it is often called, is a derivative of the *ground meristem.* It lies between the endodermis and the outer margin of the phloem of the fibrovascular bundles of stems or between the endodermis and the radial fibrovascular bundle of roots. In many stems it is composed entirely of thin-walled parenchyma cells but in others, notably climbing or twining stems, it is composed of two kinds of tissues, thin-walled parenchyma and sclerenchyma fibers. The parenchyma cells sometimes contain chloroplasts and function in the slow conduction of sap and the storage of starch. The sclerenchyma fibers give strength. In roots, the pericycle consists of one or two rows of thin-walled cells which undergo division to form lateral roots.

LATICIFEROUS TISSUE

This form of tissue comprises either *latex cells*, *laticiferous vessels*, or *secretory cells*, differing from each other in origin and method of development. **Latex cells** are elongated tubes which take their origin from meristematic cells of the embryo. Elongating with the growth of the plant, they often branch in various directions and traverse at maturity all of its organs. Such cells are abundant in the following families: *Apocyanaceæ*, *Asclepiadaceæ*, *Urticaceæ* and *Euphorbiaceæ.*

Laticiferous vessels are long branching tubes, which owe their origin to chains of superimposed cells whose transverse walls have

early become absorbed, the lumina of the cells then becoming filled with latex. They are found in various parts of roots, stems, and leaves. The branches connect with those of other tubes forming an

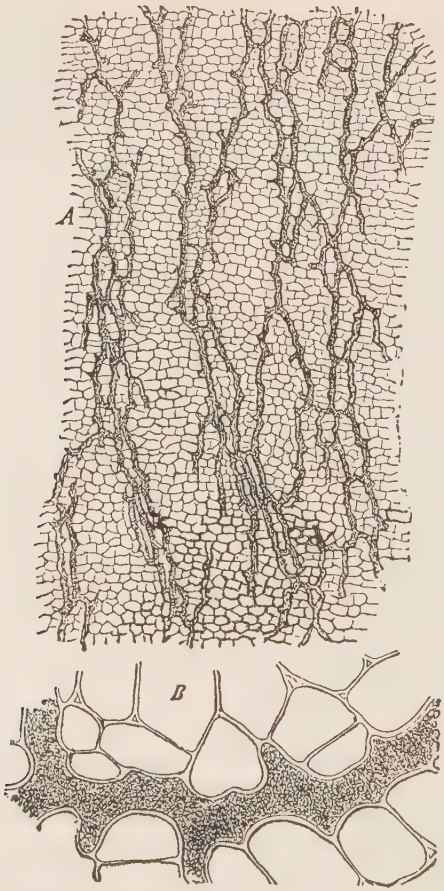

FIG. 59.—Laticiferous vessels from the cortex of root of *Scorozonora hispanica*. *A*, As seen under low power, and *B*, a smaller portion under high power. (*Stevens, after Sachs.*)

anastomosing network. These vessels occur in the following families: *Compositæ*, *Papaveraceæ*, *Campanulaceæ*, *Convolvulaceæ*, *Euphorbiaceæ*, *Araceæ*, *Oleaceæ*, *Geraniaceæ*, and *Musaceæ*.

Secretory cells with a latex-like content are probably of secondary origin in plants. They resemble in many respects latex cells and are seen in various species of the *Celastraceæ, Urticaceæ, Tiliaceæ*, and *Oleaceæ* families.

All lacticiferous elements contain a colorless, milky-white, or otherwise colored emulsion of gum-resins, fat, wax, caoutchouc and, in some cases, alkaloids, tannins, salts, ferments, etc. This emulsion is called "*latex.*"

SIEVE (LEPTOME OR CRIBIFORM) TISSUE

This tissue, found in the phloem region of fibro-vascular bundles, is a product first of the procambium and later of the cambium. It consists of superimposed, elongated, tubular cells whose longitudinal walls are thin and composed of cellulose and whose transverse walls, called "*sieve plates*," are thickened and perforated, permitting of the passage of proteids, amino-acids and amides from one cell to another. Occasionally sieve plates are formed on the longitudinal walls. Sieve tubes are usually accompanied by *companion cells* excepting in Pteridophytes and Gymnosperms. Both companion cells and sieve tubes arise by the division of the same mother-cell of the *procambium*. The companion cells may be distinguished from the mature sieve tubes by their abundant protoplasmic contents, and also by the fact that they retain their nuclei after complete maturation. Their walls are pitted where they are in contact with sieve tubes, phloem parenchyma and medullary rays. Their work is to take over food materials from the sieve tubes and pass them on to other tissues needing them for growth, repair or storage. Besides sieve tubes, companion cells, and bast fibers, parenchyma cells called "*phloem-parenchyma*" or "*sieve parenchyma*" are often found in the phloem. These cells transmit soluble carbohydrates, amino-acids and amides slowly downward and, through their communication with medullary rays, deliver food materials to them for radial distribution and storage.

TRACHEARY TISSUE

The tracheary tissue of plants comprises two kinds of elements, the *tracheæ* (ducts or vessels) and *tracheids*. They are formed first by

the procambium or plerome and later by the cambium. Both of these conduct *crude sap* (water with mineral salts in solution) upward through the roots and stems into the leaves. The *tracheæ* are very

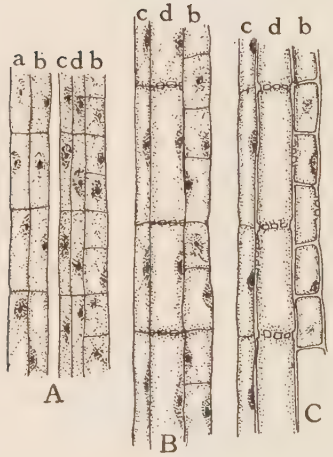

FIG. 60.

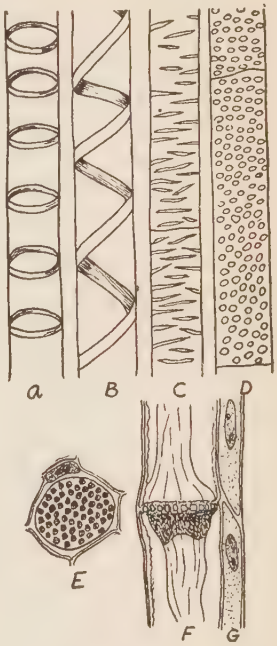

FIG. 61.

FIG. 60.—Stages in the development of sieve tubes, companion cells, and phloem parenchyma. *A*, *a* and *b*, Two rows of plerome cells; in *c* and *d*, *a* has divided longitudinally and *c* is to become companion cells; *d*, a sieve tube, and *b*, phloem parenchyma. *B*, *c*, Companion cells, and *d*, a beginning sieve tube from *c* and *d*, respectively in *A*. The cross-walls in *d* are pitted; *b*, phloem parenchyma grown larger than in *A*. *C*, The same as *B* with the pits in the cross-walls of the sieve tubes become perforations, and the nuclei gone from the cells composing the tube. (*From Stevens.*)

FIG. 61.—Vascular elements. *A*, annular tracheal tube; *B*, spiral tracheal tube; *C*, reticulated tracheal tube; *D*, pitted tracheal tube; *E*, cross-section through plate of sieve tube, and adjoining companion cell; *F*, length-wise section of sieve tube; *G*, portions of two companion cells. (*A*, *B*, *C*, *D*, *Robbins; E*, *F*, and *G*, *after Strasburger.*)

long tubes of a cylindrical or prismatic shape which are formed by the breaking down of the transverse walls between vertical groups of superimposed cells, during the growth of the plant. Thousands

of these tracheæ are arranged one above the other from the smallest branches of the root to the highest part of the stem and out into the farthest reaches of the leaves. Cross walls which are perforated with openings separate each trachea from its neighbors. In this way each line of tracheæ serves as a continuous tube for the conduction of water rapidly from root to leaf. The longitudinal or vertical walls of these tubes are of varying thickness, usually, however, thinner than those of woody fibers. The thickness is due to an infiltration of lignin upon the original cellulose wall. The walls show characteristic thickenings on their inner surfaces. These thickenings are for the purpose of giving strength to the tube while the thin parts of the wall are for the passage into and out of the tube of water with nutrient materials in solution.

Tracheæ are classified according to their markings as follows:
Annular, with ring-like thickenings.

Spiral, with spiral thickenings.

Reticulate, with reticulate thickenings.

Porous or *pitted*, with spherical or oblique slit pores.

Bordered pored, with rows of pores or slits, each being surrounded by a thickening of variable shape (circular, ellipsoidal and prismatic are the usual shapes).

Annulo-spiral, with both ring and spiral thickenings.

Scalariform, with ladder-like thickenings.

Tracheids are undeveloped ducts consisting of single cells which have thickenings similar to tracheæ but are usually smaller in size. Their ends are usually tapered but not sharply pointed. They may be distinguished from tracheæ by their smaller size and by the absence of perforations in their end walls. Like tracheæ their walls give the characteristic lignin reaction with phloroglucin and HCl. The tracheids of conifers (see Fig. 63) such as the pine, spruce, cedar, etc., usually show one row of good-sized bordered pores. Each bordered pore exhibits a wall surrounding the pore which forms a dome shaped protrusion into the cell. Like tracheæ, also, tracheids convey water with mineral salts in solution upward through the plant axis. Tracheids and medullary-rays make up most of the wood of Conifers.

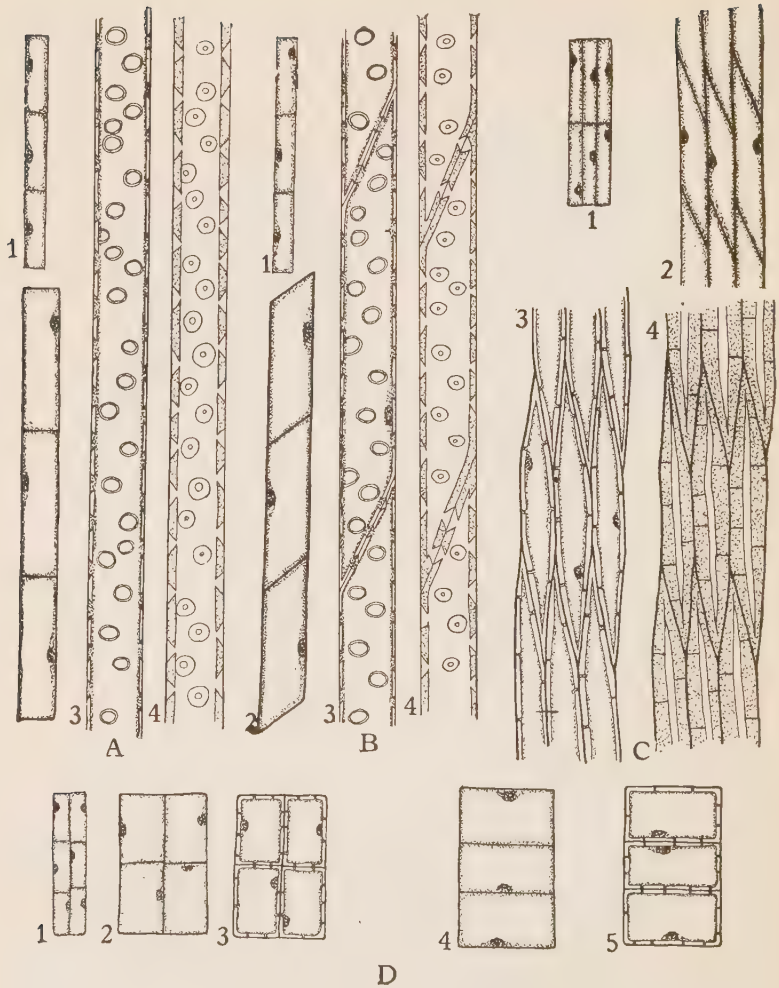

FIG. 62.—Stages in the development of the elements of the xylem. *A*, progressive steps in the development of a tracheal tube. 1, Row of plerome or cambial cells that are to take part in the formation of a tube; 2, the same at a later stage enlarged in all dimensions; 3, the cells in 2 have grown larger, their cross-walls have been dissolved out, and the wall has become thickened and pitted; 4, the walls in 3 have become more thickened, the pits have an overhanging border, the walls have become lignified as indicated by the stippling, and finally the protoplasts have disappeared, and the tube is mature and dead. *B*,

MEDULLARY RAYS

These are bands of parenchyma cells which extend radially from the cortex to the pith (primary medullary-rays)or from a part of the xylem to a part of the phloem (secondary medullary-rays). In

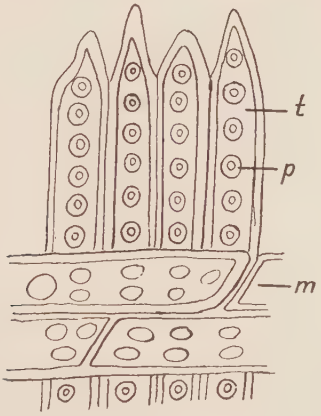

FIG. 63.—Portion of radial-longitudinal section through wood of White Pine stem. *t*, tracheid; *p*, bordered pore of same; *m*, medullary ray. Magnified.

tangential-longitudinal section they usually appear spindle-shaped, while in radial-longitudinal sections they are seen crossing the other elements. Their primary function is to supply the cambium and wood with elaborated sap formed in the leaves and conveyed away

stages in the formation of tracheids from plerome or cambial cells. The steps are the same as in *A*, excepting that the cross-walls remain and become pitted. *C*, steps in the development of wood fibers from cambial cells. 1, Cambial cells; 2, the same growth larger in all dimensions with cells shoving past each other as they elongate; 3, a later stage with cells longer and more pointed and walls becoming thickened and pitted; 4, complete wood fibers with walls more thickened than in the previous stage and lignified, as shown by the stippling. The protoplasts in this last stage have disappeared and the fibers are dead. *D*, steps in the formation of wood parenchyma from cambial or procambial cells. 1, Group of cambial or plerome cells; 2, the same enlarged in all dimensions; 3, the same with walls thickened and pitted; 4 and 5 show the same stages as 2 and 3, but here the cells have enlarged radially or tangentially more than they have vertically. The walls of these cells are apt to become lignified, but the cells are longer lived than the wood fibers. (*From Stevens.*)

by the sieve tubes and phloem parenchyma and to supply the cambium and phloem with crude sap which passes up mainly through the tracheæ and tracheids from the absorptive regions of the roots. They distribute food materials radially. They furthermore serve as storage places for starch, alkaloids, resins, and other substances.

FIBROVASCULAR BUNDLES

Fibrovascular Bundles are groups of fibers, vessels and cells coursing through the various organs of a plant and serving for conduction and support. According to the relative structural arrangement of their xylem and phloem masses, they may be classed as follows:

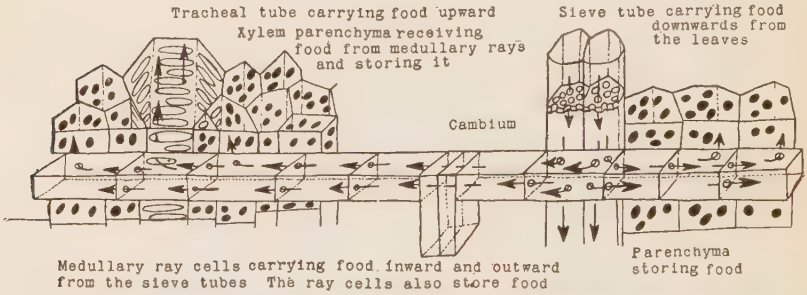
Tracheal tube carrying food upward
Xylem parenchyma receiving food from medullary rays and storing it
Sieve tube carrying food downwards from the leaves
Cambium
Medullary ray cells carrying food inward and outward from the sieve tubes The ray cells also store food
Parenchyma storing food

FIG. 64.—Diagram showing the transport of food through the sieve tubes, medullary-rays and tracheal tubes (tracheæ), and its storage in the parenchyma cells of the wood and bark. The black bodies in the cells indicate stored food. (*Stevens.*)

I. *Closed collateral*, consisting of a mass of xylem lying alongside of a mass of phloem, the xylem facing toward the center, the phloem facing toward the exterior. Stems and leaves of most Monocotyledons and Horsetails.

II. *Open collateral*, consisting of a mass of xylem facing toward the pith and a mass of phloem facing toward the exterior and separated from each other by a cambium. Stems and leaves of Dicotyledons and roots of Dicotyls and Gymnosperms of secondary growth.

III. *Bicollateral*, characterized by a xylem mass being between an inner and an outer phloem mass. There are two layers of cam-

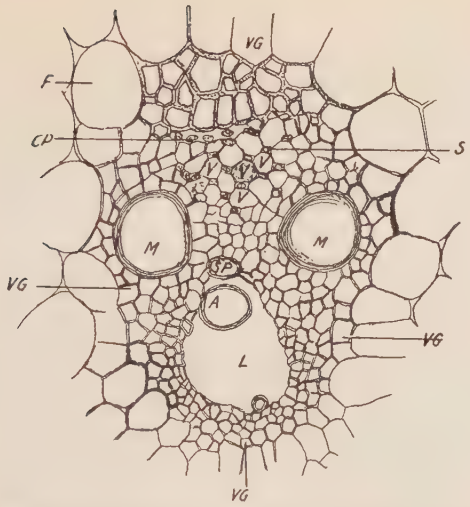

FIG. 65.—Closed collateral bundle of stem of *Zea mays*. *VG*, Bundle sheath; *L*, intercellular space; *A*, ring from an annular tracheal tube; *SP*, spiral tracheal tube; *M*, pitted vessels; *V*, sieve tubes; *S*, companion cells; *CP*, crushed primary sieve tubes; *F*, thin-walled parenchyma of the ground or fundamental tissue. (*From Sayre after Strasburger.*)

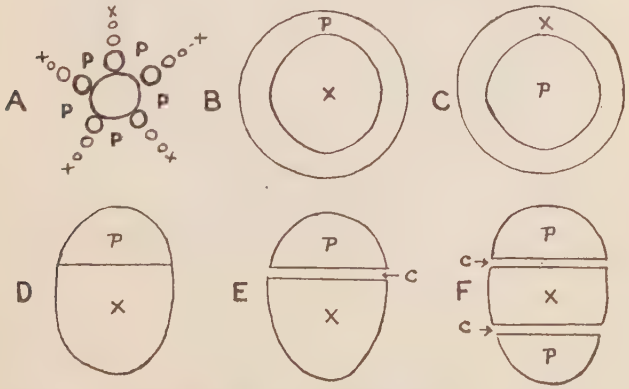

FIG. 66.—Diagrams illustrating the arrangement of the regions in different types of fibrovascular bundles. In each diagram x represents xylem; P, phloem and C, cambium. A, Radial bundle; B, concentric bundle of fern stem type; C, concentric bundle of monocotyl type; D, closed collateral bundle; E, open collateral bundle; F, bi-collateral bundle.

bium cells, one between the xylem and inner phloem mass, the other between the xylem and outer pholem mass. Seen chiefly in stems and leaves of the *Cucurbitaceæ*, *Combretaceæ*, *Loganiaceæ*, *Apocynaceæ*, *Asclepiadaceæ*, *Oleaceæ*, *Convolvulaceæ*, *Gentianaceæ* and *Solanaceæ*.

IV. *Concentric*, characterized by a central xylem mass surrounded by a phloem mass or *vice versa*. No cambium present.

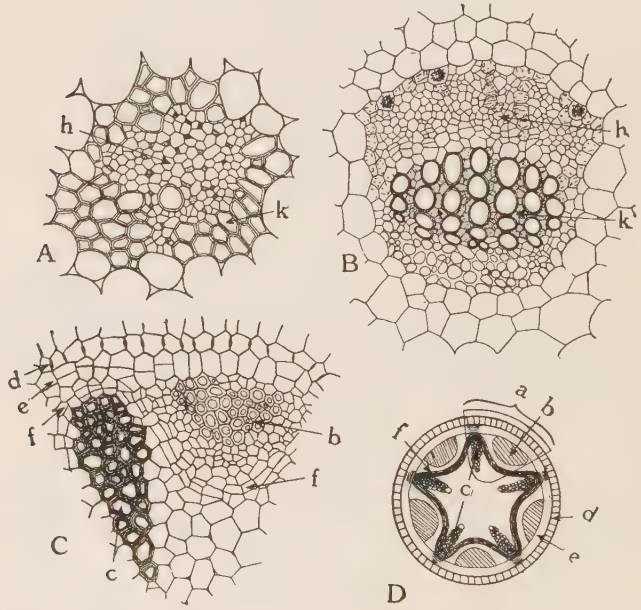

FIG. 67.—Vascular bundles. A, the concentric-monocotyl type, with xylem, k, surrounding the phloem, h. B, the collateral type, with phloem, h, standing in front of the xylem, k, C, a portion of the radial type (undergoing transition) shown complete in D, where the part outlined at *a* corresponds to C. c, xylem, b, phloem, f, cambium ring; e, pericycle; d, endodermis. Pericycle and endodermis are not parts of the bundle. (*From Stevens after Haberlandt.*)

(*a*) *Concentric*, with xylem central in bundle. Seen in stems and leaves of nearly all ferns and the *Lycopodiaceæ*.

(*b*) *Concentric*, with phloem central in bundle. Seen in stems and leaves of some *Monocotyledons*. *Examples:* Calamus and Convallaria rhizomes.

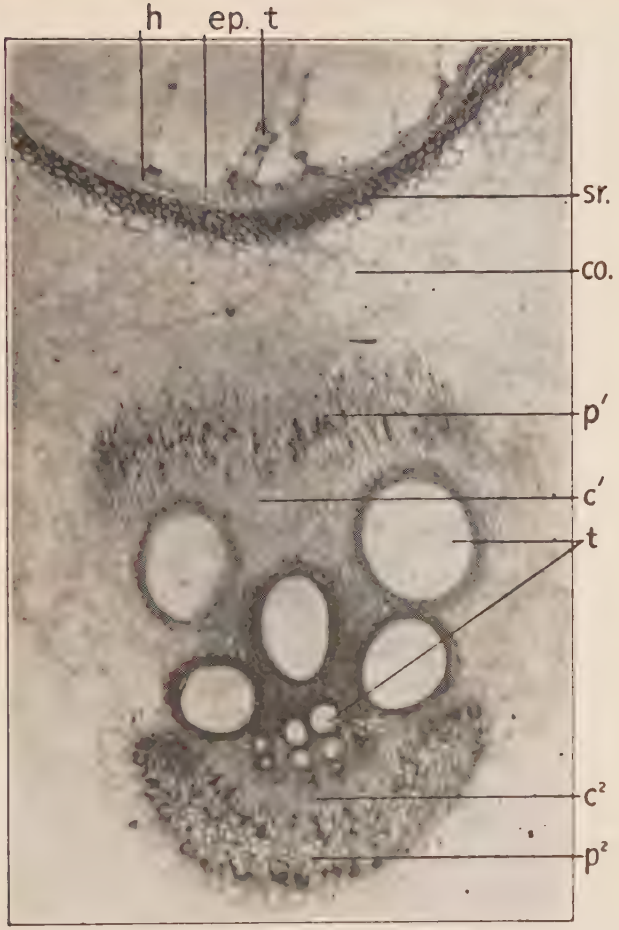

FIG. 68.—Transverse section of representative portion of Pumpkin (*Cucurbita Pepo*) stem showing a bi-collateral bundle and outer tissues. Epidermis (*ep*) with trichomes (*t*); hypodermis (*h*); sclerenchyma ring (*sr*); cortex (*co*); and external phloem (p^1); outer cambium (c^1); tracheæ of xylem (*t*); inner cambium (c^2) and internal phloem (p^2) of the bi-collateral bundle. Photomicrograph × 140.

V. *Radial*, characterized by a number of xylem and phloem masses alternating with one another. Seen in the roots of all *Spermatophytes* and *Pteridophytes*.

Xylem[1] is that part of a fibro-vascular bundle that usually contains wood parenchyma cells, tracheæ and tracheids. It frequently

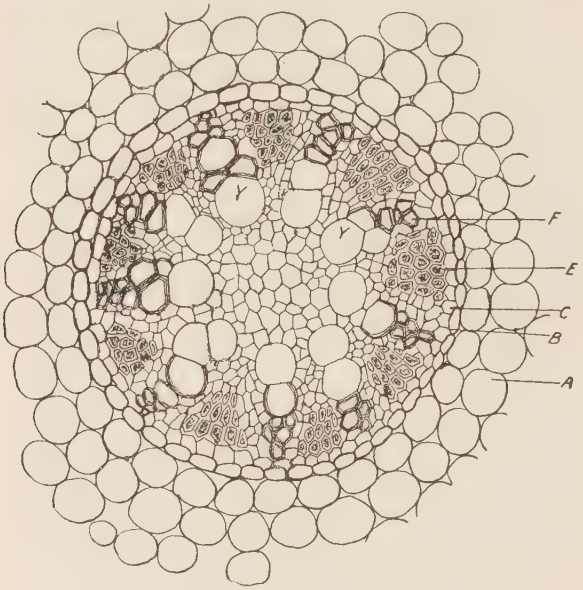

FIG. 69.—Cross-section through a portion of a root of *Acorus calamus*, a monocotyledon. *A*, Cortical parenchyma; *B*, endodermis; *C*, pericycle; *E*, phloem; *F*, xylem. At *Y*, *Y*, are large tracheal tubes, which were formed last, the narrow tubes near the periphery of the xylem being formed first. At the center of the root, within the circle of the polyarch, radial vascular bundle, occur thin-walled parenchymatous pith cells. (*From Sayre after Frank.*)

contains, in addition, wood fibers. The xylem of most Gymnosperms is devoid of tracheæ.

Phloem[2] is that part of a fibro-vascular bundle that contains sieve tubes, phloem parenchyma cells, and often bast fibers.

[1] The conducting elements of the xylem comprising tracheæ, tracheids and wood parenchyma constitute the *hadrome*.

[2] The conducting elements of the phloem which comprise the sieve tubes, companion cells and phloem parenchyma constitute the *leptome*.

SECRETION SACS (SECRETION CELLS)

These were formerly parenchyma cells which sooner or later lost their protoplasm and nucleus and became receptacles for oil, resin, oleoresin, mucilage or some other secretory substance. They are generally found in parenchyma regions of stems, roots, leaves, flower or fruit parts and frequently possess suberized walls. Good illustrations of these structures may be seen in Ginger and Calamus.

INTERCELLULAR AIR SPACES

Intercellular air spaces are cavities filled with air found between cells or groups of cells throughout the bodies of higher plants. Their function is to permit of the rapid movement of atmospheric gases through the entire plant body. They are formed either by the

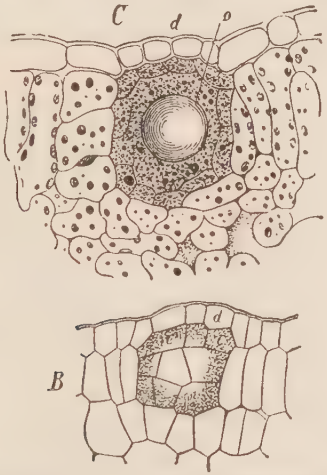

FIG. 70.—Lysigenous gland in the leaf of *Dictamnus fraxinella*. *B*, young glands, with cells beginning to secrete oil; *C*, mature gland where the secreting cells have broken down and left their secretion in the cavity thus formed; *o*, large drop of secreted oil. (*Stevens after Sachs.*)

breaking down of the middle lamella of the cell walls, where several cells come together, and a later separation of the cells at these places (*Schizogenous intercellular-air-spaces*), or by a breaking down and disappearance of cell walls common to groups of cells (*lysigenous intercellular-air-spaces*). In terrestrial plants which live in middle regions (*mesophytes*) and in desert plants (*xerophytes*) the inter-

cellular-air-spaces are averagely small and more or less angular. In plants of swamp or marsh habit they are medium-sized, while in those which live entirely in the water (*hydrophytes*) they are of large size and more or less rounded.

INTERNAL SECRETION GLANDS AND RESERVOIRS

These structures are either found as globular cavities as in Orange and Lemon Peel and Eucalyptus leaves, containing oil or oil and

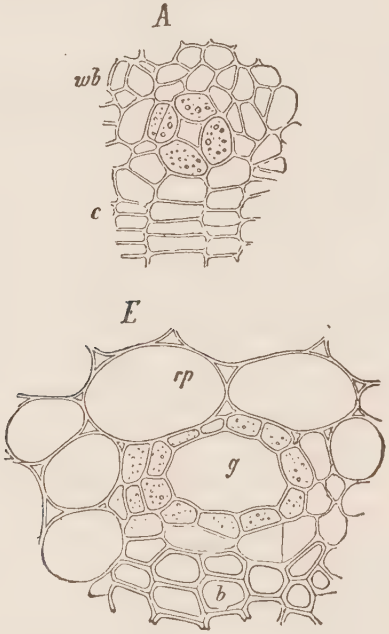

FIG. 71.—Schizogenous secretion reservoir (resin duct) as seen in cross section in the young stem of English Ivy. *A*, early and *E*, later stage in the formation of the duct. *g*, the mature duct; *c*, cabmium; *wh*, phloem; *b*, bast fibers. (*Stevens, after Sachs.*)

resin, when they are called *internal glands*, or, as tube-like spaces filled with hydrocarbon principles, such as are found in Pine leaves and stems, when they sometimes receive the name of *secretion canals* or *reservoirs*. In the Parsley family these canals are found in the fruits, where they are called *vittæ*. Occasionally they are named according to the nature of their contents—resin or oil canal or reser-

voir, etc. The *internal glands* usually arise by the division of a cell or group of cells of the ground meristem but sometimes the dermatogen gives rise to them, as in Clove, Myrtle, Asarum, etc., or both the ground meristem and dermatogen may contribute to the formation of the same gland. Internal glands are termed *schizogenous* when the secreting cells split apart at the center of the group and draw away from the line of separation; when they break down

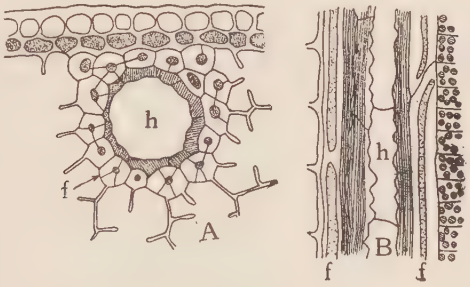

FIG. 72.—Resin duct (secretion reservoir) in leaf of *Pinus sylvestris*, in cross-section at *A*, and in longitudinal section at *B*; *h*, cavity surrounded by the secreting cells; *f*, *f*, sclerenchyma fibers surrounding and protecting the duct. (*Stevens after Haberlandt.*)

completely, leaving their secretion in the resulting cavity they are termed *lysigenous*. The *secretion reservoirs*, also called *internal tubular glands*, are formed by a long vertical series of cells forming a space schizogenously or lysigenously. The schizogenous type of gland and reservoir is lined with a layer of cells, usually more or less flattened, which are characterized by possessing large nuclei. To this layer has been assigned the name "secretory epithelium."

Classification of Tissues According to Function.—According to their particular function, tissues may be classified as follows:

I. CONDUCTING TISSUES	Parenchyma (fundamental tissue) Medullary rays Xylem cells (wood parenchyma) Tracheæ (ducts) and tracheids Phloem cells (phloem parenchyma) Sieve tubes Companion cells
II. PROTECTIVE TISSUES	Epidermis (outer cell walls cutinized) Cork (suberized tissue)

III. Mechanical Tissues	Bast fibers
	Wood fibers
	Sclerenchyma fibers
	Pericyclic fibers
	Stone cells
	Collenchyma
IV. Secreting Tissues	Internal glands
	Secretion reservoirs
	External glands (glandular hairs)
V. Storage Tissues	Parenchyma
	Reserve parenchyma
	Medullary-rays
	Wood parenchyma
	Phloem parenchyma
	Laticiferous tissue
VI. Meristematic Tissues	Primordial meristem
	Dermatogen (protoderm)
	Periblem (ground meristem)
	Plerome (procambium)
	Cork cambium
	Cambium

CHAPTER VIII

THE ROOT

The root is that part of the plant that grows into or toward the soil, that never develops leaves, rather rarely produces buds, and whose growing apex is covered by a cap.

The chief functions of a root are absorption, storage and support. Its principal function is the absorption of nutriment and to this end it generally has branches called **rootlets** that are covered with **root-hairs** which largely increase the absorbing surface. These **root-hairs** are of minute and simple structure, being merely elongations of the epidermis of the root, for a short distance back of the root cap, into slender tubes with thin walls. Like other living cells, each shows cytoplasm, sap vacuoles containing cell sap, a nucleus with

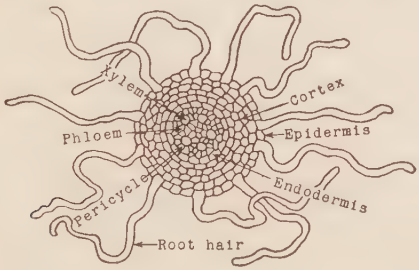

FIG. 73.—Cross-section of rootlet in the region of the root-hairs. (*From Stevens.*)

nuclear membrane, outer plasma membrane against the covering cell wall of cellulose and vacuolar membranes around sap vacuoles. That portion of the epidermis which bears root-hairs is called the **piliferous layer.**

Soil and Water Relation.—Under conditions favorable to the growth of land plants, the soil is open and porous, the particles of soil being separated by spaces containing air, while every soil particle is enveloped by a film of water. The root-hairs are in close contact

with these soil particles (Fig. 76) and soil water from the films surrounding them soaks through their cell walls into the root-hairs. This soil water is a solution of various mineral salts. In order to understand how this solution passes into the root-hairs, it is essential to first understand the processes of diffusion and osmosis.

Diffusion.—This is the process whereby the particles of substances making up a solution tend to be uniformly intermingled. It may be

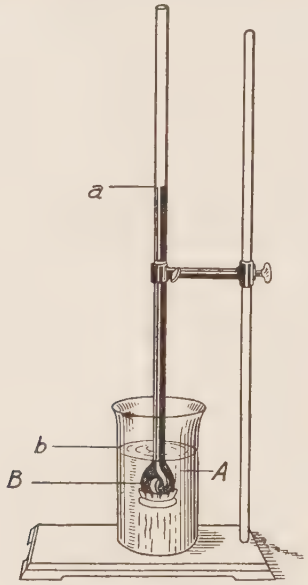

FIG. 74.—Osmosis. The more rapid inflow of liquid from *A* to *B* has elevated the liquid surface within from *b* to *a*. (*From Brownell's General Science.*)

observed by introducing a crystal of copper sulphate into a tumbler of water. The crystal slowly dissolves and the particles of which it is composed in time diffuse themselves equally throughout the water, so that the water is colored uniformly blue. The movement of the particles of the dissolved copper sulphate from the region of greater density or concentration to that of less implies a pressure which is termed diffusion tension.

Osmosis.—If the denser copper sulphate solution in the bottom of the tumbler were separated from the less dense water above by a

semipermeable membrane such as parchment or bladder, diffusion would take place through the membrane and the water above would become colored as proof of this diffusion. Moreover, the water above the membrane would pass through it in the opposite direction and more rapidly than the solution of the copper salt. It would continue to do so until the solution was of the same density on both sides of the membrane. *Diffusion through a porous membrane is known as osmosis.* It is a well-known law of physics that when two liquids or gases of different densities are separated by a porous (osmotic) membrane, diffusion through the membrane will take place until the density of the fluids or gases becomes the same on each side. The diffusion will be more rapid from the less dense to the more dense region.

Osmosis Applied to Root-hairs.—Normally the cell sap of the root-hairs is a denser liquid than the soil water outside of the hairs.

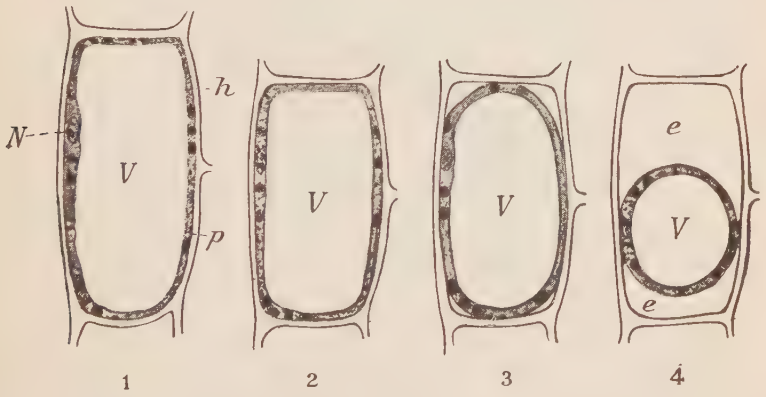

FIG. 75.—Successive stages of plasmolysis. *N*, nucleus; *V*, vacuole. (*Palladin after de Vries.*)

The outer plasma membrane and the vacuolar membranes represent porous osmotic membranes separating the denser solution within the hair from the less dense soil water without. The soil water imbibed by the cell wall passes by osmosis through the outer plasma membrane, diffuses through the cytoplasm to the vacuolar membranes through which it passes by osmosis into the sap vacuoles and there becomes a portion of the cell sap.

The kind of osmosis just indicated is known as *endosmosis* or osmosis from without in. A reverse process takes place when small traces of CO_2, acid and other substances are excreted, *e.g.*, passed out of the root-hair. This is called *exosmosis*.

Turgor.—If the cell sap of the root-hair or any other plant cell becomes concentrated above that of the soil solution, the cell is caused to bulge. This bulging is a manifestation of osmotic pressure within and the condition resulting is termed *turgor*. Cells of plants exhibiting this phenomenon are said to be in the state of turgescence

FIG. 76.—Root-hairs, with soil-particles adhering. (*Gager, after Sachs.*)

or rigidity. Since turgor is coexistent with growth, conditions affecting turgescence affect at the same time all growth processes.

Plasmolysis.—If root-hairs or other plant cells are placed in solutions of a greater density than that of their cell sap content, as for instance 5 to 10 per cent. salt or sugar solution, exosmosis becomes more rapid than endosmosis. The cell sap is extracted more rapidly than the fluid enters from without, with a result that the protoplasm is loosened from the cell wall and caused to collapse. This condition is called *plasmolysis* and the cell is said to be *plasmolyzed*. Plasmolysis throughout a tissue or organ results in wilting.

Many plants wilt on account of too high a concentration of soil solutes.

Absorption of Nutrient Salts.—The plasma membranes of all living plant cells are permeable to certain solutes (substances in solution) and impermeable to others. These membranes in the root-hairs absorb each solute particle separately and according to the need or attraction for that substance; this is called *selective absorption.*

The higher green plants vary greatly in respect to their mineral requirements. Of thirty-one elements found in the ash of plants, only eleven occur regularly, *e.g.*—sulphur, chlorine, phosphorus, silicon, potassium, sodium, calcium, magnesium, iron, aluminum (a trace) and manganese (a trace). Seven elements are absolutely required in the form of water-soluble salts for the normal growth of all higher green plants. These seven are termed *essential elements* and comprise the following: *nitrogen*, *sulphur*, *phosphorus*, *calcium*, *potassium*, *magnesium* and *iron.*

Importance of Essential Elements.—*Nitrogen*, *sulphur* and *phosphorus* are constituents of proteids and so of protoplasm and are essential to their formation.

Calcium not only neutralizes many harmful substances but facilitates the absorption of other salts and is necessary for normal leaf development.

Potassium accompanies carbohydrates and is thought to play a part in their formation.

Magnesium is a constituent of chlorophyll and accompanies proteins.

Iron is essential to the formation of chlorophyll although it is not a component of that substance. When deprived of iron, green plants become pale and chlorotic, even though they are grown in light.

While not absorbed as mineral salts, carbon, hydrogen and oxygen are likewise indispensable elements. The very life of all plants depends upon their availability. All three enter into the formation of proteins, carbohydrates and protoplasm and the first two are essential to the formation of fats and oils. Water, which makes up the greatest part of protoplasm and forms the solvent for soil salts,

consists of a combination of two parts of hydrogen to one part of oxygen.

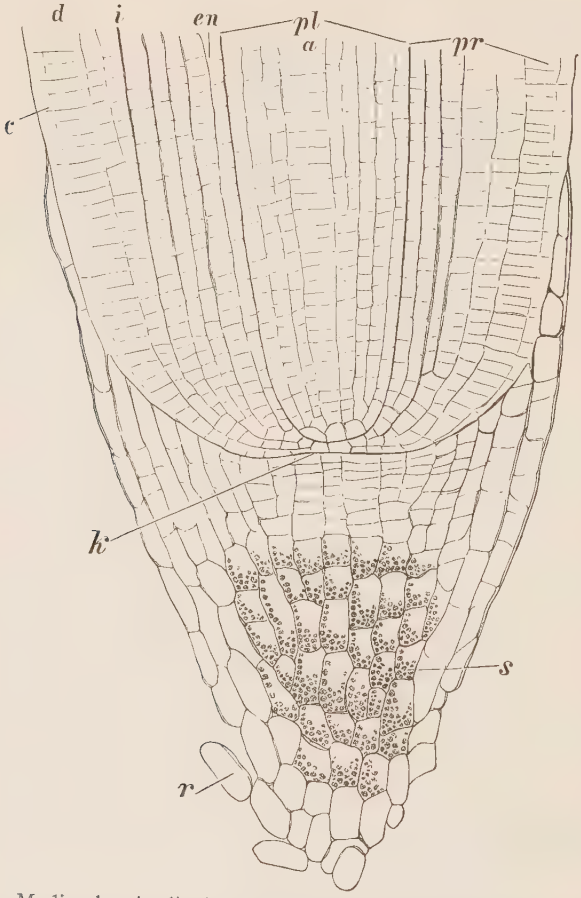

FIG. 77.—Median longitudinal section through the root tip of the barley. *k*, calyptrogen; *d*, dermatogen, *c*, the thick outer wall of the same; *pr*, periblem; *pl*, plerome; *en*, endodermis; *i*, intercellular-air-spaces; *a*, cell rows which will develop the central vessels; *r*, detached cells of root cap; *s*, starch grains in cells of root cap. × 180. (*After Strasburger and Koernicke in Lehrbuch der Botanik.*)

Non-essential Elements Absorbed by Root-hairs.—These elements include those which are also absorbed as water-soluble

salts but which are not required for the normal growth of all plants. In many specific instances, however, they may be beneficial.

Silicon is an abundant element in many plants, notably the grasses, sedges and scouring rushes. It occurs in the ash of these plants as silicon dioxide (SiO_2) and in most soils as silicic acid (H_2SiO_3). It is deposited mainly in cell walls of the peripheral parts of stems, leaves and seeds and affords protection from penetration by the hyphæ of parasitic fungi as well as from animal attack such as plant lice and scale insects.

Chlorine, another inessential element, probably has an influence on the translocation of carbohydrates from leaves to other organs under natural conditions. Most plants can attain complete development without it. The question of its rôle still remains unsettled.

Aluminum is only occasionally found in plants. It is known to influence the color of flowers in *Hydrangea hortensis*. When grown in forest or moor soil this species has reddish flowers but when grown in soil containing soluble aluminum compounds, its flowers are blue.

Root Cap.—The tip of each root or rootlet is protected by a sheath- or scale-like covering known as the *root cap* or *calyptra*. This is a mass of cells which not only protects the delicate growing point, but serves as a mechanical aid as the root pushes its way through the soil.

Growing Point. –The growing point of the root of a seed plant consists of a group of actively dividing cells directly beneath the root cap. These cells make up the tissue called the *primordial meristem*.

Primary Meristems.—Just in back of the primordial meristem, the cells have begun to show differentiation into three groups of tissues called *primary meristems* or *generative tissues*. In this region the cells grow in length rapidly and ultimately give rise to the adult primary tissues of the root.

Generative Tissues.—The generative tissues directly back of the growing point are, passing from the center toward the outside: *plerome* or *procambium*, producing fibro-vascular tissue (xylem and phloem) and pith; *periblem* or *ground meristem*, producing cortex including endodermis and pericycle; and *dermatogen* or *protoderm*,

producing epidermis. The name calyptrogen has been given to those cells of the primordial meristem which form the root cap. (Cf. Fig. 77.)

Differences Between Root and Stem

The Root	*The Stem*
1. Descending axis of plant.	1. Ascending axis of plant.
2. Growing point sub-apical, being covered by the root cap.	2. Growing point apical, but covered by protective bud scales or young foliage leaves.
3. Contains no chlorophyll.	3. Chlorophyll sometimes present.
4. Does not bear leaves or leaf rudiments.	4. Bears leaves and modifications.
5. Branches arranged irregularly, and arising from deeper tissue.	5. Branches with mathematical regularity, the branches arising at surface of stem, in axils of leaves and from nodes.
6. No division into nodes and internodes.	6. Division into nodes and internodes.
7. Internal structure different.	7. Internal structure different.

Classification of Roots as to Order.—1. *Primary or first root*, a direct downward growth of the radicle (from embryo within seed), which, if greatly in excess of the lateral roots, is called the *main* or *tap root.*

2. *Secondary roots* are lateral branches of the primary root. They may, in turn, give rise to finer branches, or rootlets. Both primary and secondary roots may be either *fibrous* or *fleshy.*

3. *Adventitious roots* are such as arise from any part of the plant other than the seed embryo or normal root system. Examples: Roots developing on *Bryophyllum* and *Begonia* leaves when placed in moist sand; roots arising from stems of climbing plants or from stem cuttings.

4. *Prop roots* or *brace roots* are such as grow out of the stem a short distance above the soil and extend diagonally into the ground, serving as supports to the stem. Examples: Indian Corn and Pandanus.

5. *Epiphytic roots* are the roots of epiphytes or air-plants, many of which are common to tropical forests. In some instances, as in *Vanilla* and other epiphytic Orchids, these roots, arising from aerial

stems, hang down free in the air and absorb water from rain by means of their several layered epidermis called a *velamen*. In others, as in the English Ivy, several short roots grow out of the stem at various

FIG. 78.—*Vanilla planifolia*, an epiphyte, growing on a tree in Jamaica, W. I. (*Gager, after Maxon, U. S. Dept. Agr.*)

intervals and adhere by their tips to walls, thus serving as supports for climbing.

The Banyan (*Ficus religiosa*) of India can extend itself over large areas by means of its aerial roots. These extend down vertically

from horizontal branches and form trunks, upon anchoring themselves in the soil.

6. The roots of parasitic plants are known as *Haustoria*. These penetrate the bark of plants upon which they find lodgment, known as hosts, and absorb nutritious juices from them. The *Mistletoe, Dodder* and *Gerardia* are typical parasitic higher plants.

FIG. 79.—Dodder (*Cuscuta* sp.) in flower. Parasitic on a golden rod (*Solidago ulmifolia*). (*Gager, photo by Elsie M. Kittredge.*)

Classification of Roots as to Form.—*Fusiform*, or *spindle-shaped*, like that of the radish or parsnip.

Napiform, or *turnip-shaped*, somewhat globular and becoming abruptly slender then terminating in a conical tip, as the roots of the turnip.

Conical, having the largest diameter at the base then tapering, as in the Maple and Aconite.

Fibrous, when very slender or fiber-like, as in the grasses and cereals.

Tortuous, when irregularly bent or twisted, as Pareira.

Nodose, when swollen at intervals in its course and fibrous otherwise, as the roots of the Dropwort.

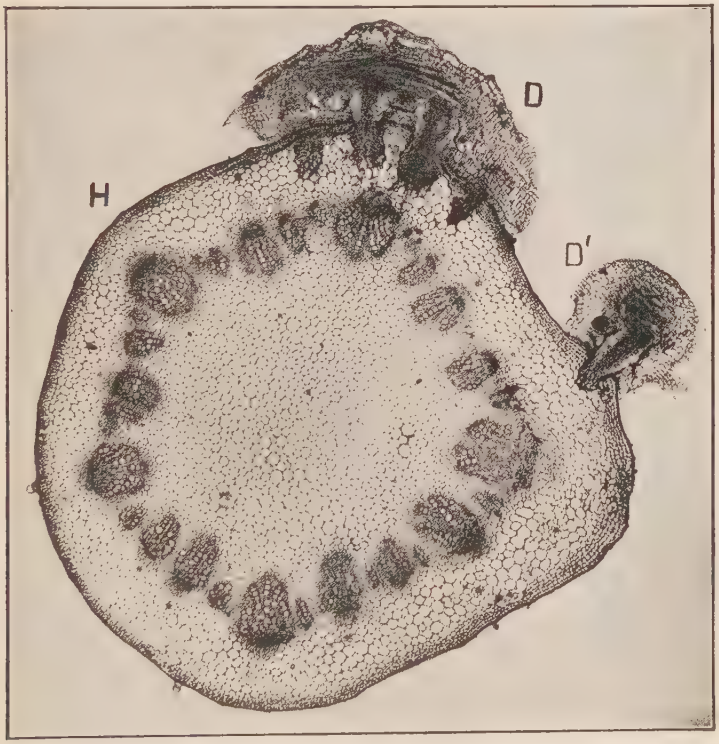

FIG. 80.—Photomicrograph of a transverse section of the stem of a dicotyledonous host-plant infested with the parasite, dodder. Note the haustoria extending from the Dodder (D, D′) into the cortex of the host (H). Greatly enlarged. (*Gager.*)

Moniliform, when the swellings occur at very close intervals giving the root the appearance of a close chain of beads.

Tuberous, when fleshy, swollen, especially in the central portion, and resembling tubers in shape as in Jalap and the Sweet Potato.

Fascicled, when a number of thickened and similarly looking roots occur in a cluster, as in the Dahlia.

Root Consistency or Texture.—In this particular, roots are termed *woody*, when the hard, lignified tissue predominates and *fleshy*, when

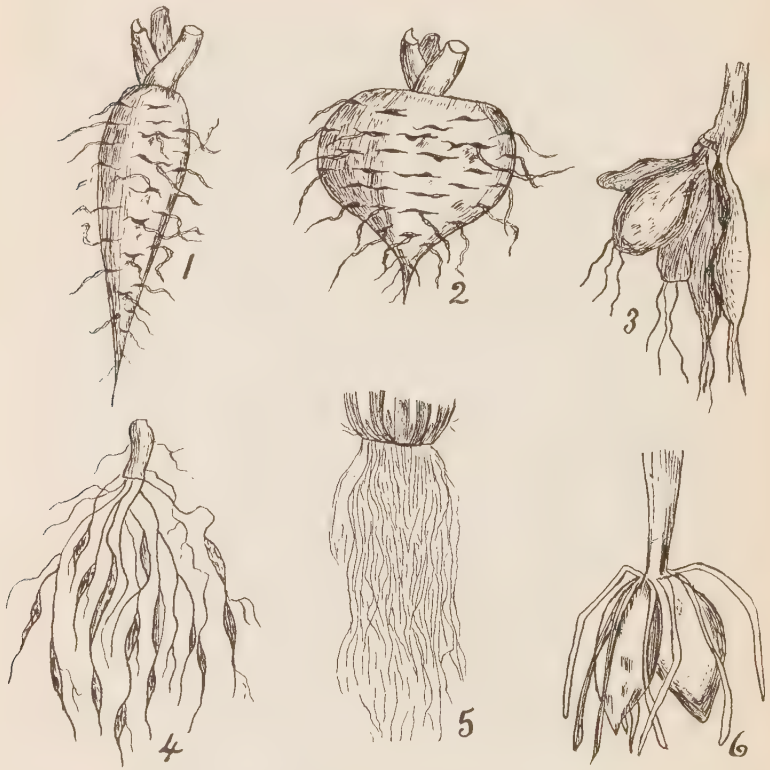

FIG. 81.—Root systems. Fleshy tap root of Carrot (1); napiform root of a Radish (2); multiple, tuberous roots of a Dahlia (3); nodose roots of the Dropwort (4); fibrous roots of a Grass (5); fibrous-tuberous root system of an Orchid (6).

the soft cellular tissues predominate. Fleshy roots may be (1) simple or single or (2) multiple, when a number arise from the base of the stem in a cluster, as in the Dahlia

Duration of Root.—Plants are classified according to the duration of the root, as follows:

1. *Annual plants* are *herbs* with roots containing no nourishment for future use. They complete their growth, producing flowe, fruit and seed in a single season, then die. Example: Stramonium.

2. *Biennial* plants develop but one set of aerial organs the first year, *e.g.*, the leaves, and, as Digitalis, Conium, etc., a large amount of reserve food material is stored in the roots for the support of the plant the following season, when it flowers, fruits and dies.

3. *Perennial plants* are those whose roots or underground stems and roots live indefinitely, as trees, shrubs and perennial herbs.

Root Histology.—The histology of roots varies, depending upon character of the surrounding water relations or soil in which the plants are accustomed to live which may be aquatic, mesophytic, halophytic or xerophytic, etc.

Aquatic plants or *hydrophytes* are those which live in water or wet soil as the water-lilies, calamus, cat-tails, etc.

Mesophytic plants or *mesophytes* are those which thrive with a moderate supply of moisture, as most of the land plants of our fields and meadows.

Halophytic plants or *halophytes* are those which thrive in salt marshes, on saline flats near the sea coast and on the alkali flats of the interior, as the salt marsh samphire, the mangroves, chenopodium, etc.

Xerophytic plants or *xerophytes* are those which thrive in very dry soil, as the cactus, century plant, hemlock, spruce, etc.

Histology of Monocotyl Root

In this connection we will discuss only the type of greatest pharmacognic importance, *i.e.*, the mesophytic type as seen in its most typical form in the transverse section of Honduras Sarsaparilla root.

Examining such a section from periphery toward the center, one notes the following:

1. *Epidermis* (derived from dermatogen) of a single layer of cells many of which give rise to root-hairs.

2. *Hypodermis* (derived from periblem) of two or three layers of cells whose walls are extremely thickened.

3. *Cortex* (derived from periblem) consisting of a broad zone of parenchyma cells many of which contain starch grains.

4. *Endodermis* (derived from periblem) of one layer of endodermal cells whose walls are extremely thickened through the infiltration of suberin and lignin.

FIG. 82.—Part of a transverse section of Honduras sarsaparilla root showing epidermis (*e*), root hair (*h*), hypodermis (*h*), cortex (*c*), endodermis (*en*), pericambium (*p*), trachea of one of the numerous xylem patches (*t*), and pith (*m*). The phloem patches are the small, oval, cellular areas wedged in between the outer portions of adjacent xylem masses. (Photomicrograph.)

5. *Pericycle*, also called pericambium (derived from periblem), of one or two layers of meristematic cells whose walls are extremely thin.

6. A *radial fibro-vascular bundle* (derived from plerome) of many alternating xylem and phloem patches and hence *polyarch*. The phloem tissue consists of phloem cells and sieve tubes. The xylem is composed of xylem cells, tracheæ and wood fibers.

7. *Medulla* or *pith* (derived from plerome) composed of parenchyma cells containing starch and often showing xylem patches cut off and enclosed within it.

The tissues within the endodermis collectively constitute the **stele.**

The Sarsaparilla root resembles most monocotyl roots in showing no secondary increase in thickness which is sometimes called secondary growth. Secondary increase in thickness is the rule in roots of most dicotyledons and gymnosperms and is due to the formation in those roots of a cambium. No such tissue arises in most monocotyl roots. However, some difference in diameter will often be noted between sections cut through the same root at different levels above the root cap, those cut nearer the stem end being broader. The explanation is that the cells in the broader sections have become larger through the process of growth, rather than having been augmented in number.

HISTOLOGY OF DICOTYL ROOTS

The typical dicotyl root is a tetrarch one, which is a root whose radial bundle exhibits four xylem patches alternating with four phloem patches. These roots usually have an unlimited power of growth. The early growth is called *primary growth* which means first growth and is represented in sections cut a little above the root cap in the region of the root hairs. Above the region of primary growth is the *region of transition* where changes are taking place in the root which lead to the appearance of secondary structure.

A transverse section of a dicotyl root in its **young growth** shows the following structure from periphery toward center:

1. *Epidermis* (from dermatogen) with cutinized outer walls, the cells often elongating to form root-hairs.

2. *Primary cortex* (from periblem) of parenchyma cells with usually small intercellular spaces. Whenever the outermost layer or layers of cells of this region have more thickened walls than those beneath,

the term *hypodermis* is employed for this outer portion of the cortex.

3. *Endodermis* (from periblem) or innermost layer of cells of the cortex, with lenticularly thickened radial walls.

4. *Pericambium* (Pericycle) (from periblem) of one to two layers of actively growing cells which may produce side rootlets.

5. *Radial fibro-vascular bundle* (from plerome) of four, less frequently of two, three, five or six *primary phloem* (protophloem)

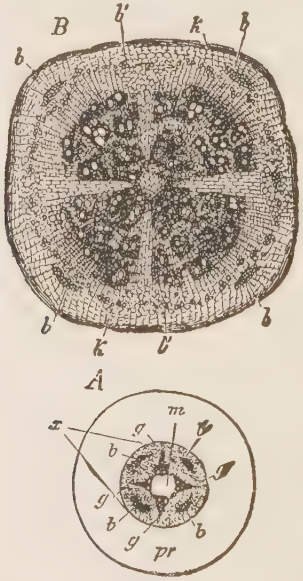

FIG. 83.—Cross-section of a young root of *Phaseolus multiflorus*. *A*, *pr*, cortex; *m*, pith; *x*, stele or central cylinder—all tissue within the pericycle, inclusive; *g*, primary xylem bundles; *b*, primary phloem bundles. *B*, cross-section of older portion of root; lettered as in *A*; *b'*, secondary phloem; *k*, cork. (*Stevens, after Vines.*)

patches alternating with as many *primary xylem* (protoxylem) arms. It is not uncommon to find bast fibers along the outer face of each phloem patch. Xylem has spiral tracheæ, internal to these a few pitted vessels, then, as root ages, more pitted vessels, also xylem cells and wood fibers make their appearance.

6. *Pith* (from plerome), a small zone of parenchyma cells.

Histology of Transitional Growth and Development of Secondary Structure.

At about six weeks one notes cells dividing by tangential walls in the inner curve of each phloem patch. This is *intrafascicular cambium*. Its cells in each location start to cut off on their inner side a quantity of *secondary xylem* and add a little *secondary phloem* on their outer side. The protophloem tracts become pushed out and the protoxylem tracts in. The pith disappears as the protoxylem encroaches upon it. Secondary xylem finally fills up the patches between the arms. The pericambium has a tendency to start division into an outer and an inner layer. The outer layer becomes a *cork cambium* (phellogen) surrounding the bundle inside of the endodermis. It cuts off cork tissue on its outer face, hence all liquid material is prevented from filtering through and cortex including endodermis, as well as the epidermis, shrivel, dry up and separate off at the age of two to three months. The cork cambium (phellogen) lays down *secondary cortex* internal to itself and external to the phloem.

Patches of cells of the *inner layer* of *pericambium* divide rapidly and are called *interfascicular cambium*. These join the *intrafascicular cambium* to form a continuous *cambium* ring which then cuts off additional secondary xylem on its inner face and additional secondary phloem on its outer face pushing inward the first-formed or protoxylem and outward the first-formed or protophloem. Medullary-rays are formed by the cambium as it cuts off secondary xylem and secondary phloem elements.

Thus, in a transverse section made through a portion of a Dicotyl root showing *secondary growth*, the following regions are noted passing from periphery to center:

1. Cork
2. Cork cambium (phellogen)
3. Secondary cortex

Fibro-vascular tissue.

4. Protophloem
5. Secondary phloem
6. Cambium
7. Secondary xylem
8. Protoxylem

9. Strands of cells extending radially from the cortex to the center of the section separating each open fibro-vascular bundle from its neighbors. These are called medullary-rays.

The xylem or wood portion of each fibrovascular bundle appears as a wedge placed between the xylem portions of two medullary-rays and so is sometimes called a **wood wedge.** The xylem portions of the medullary-rays between the wood wedges are termed **wood-rays.**

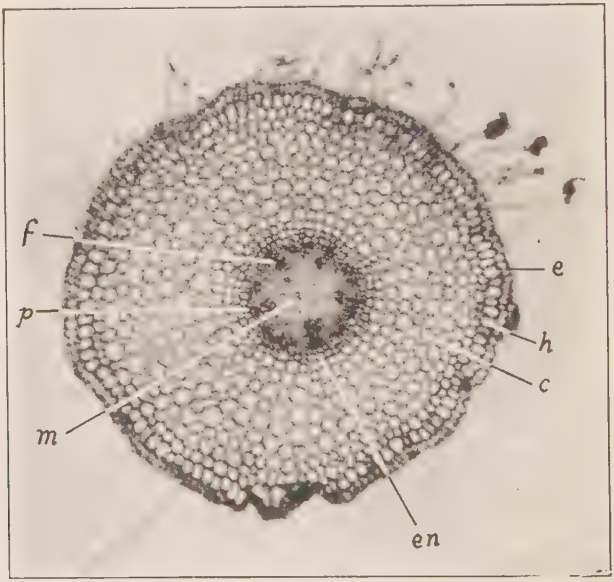

FIG. 84.—Photomicrograph of a transverse section of a California Privet root of primary growth showing epidermis (*e*); hypodermis (*h*); cortex (*c*); endodermis (*en*); pericambium (*p*); a xylem arm of the radial bundle (*f*) and pith (*m*).

Histology and Development of a Typical Dicotyl Root (California Privet).—A. Make a permanent mount of a cross section of the root of the California Privet (*Ligustrum Californicum*) cut just above the root cap, and note the following structures, passing from periphery toward the center (see Fig. 84):

1. *Epidermis*, composed of a layer of epidermal cells whose outer walls have been infiltrated with a substance called *cutin*.

2. *Hypodermis*, a layer of somewhat thick walled cells just beneath the epidermis.

3. *Cortex*, composed of cortical parenchyma cells with small, angular, intercellular-air-spaces.

4. *Endodermis*, or innermost layer of cells of the cortex, whose radial walls are lenticularly thickened.

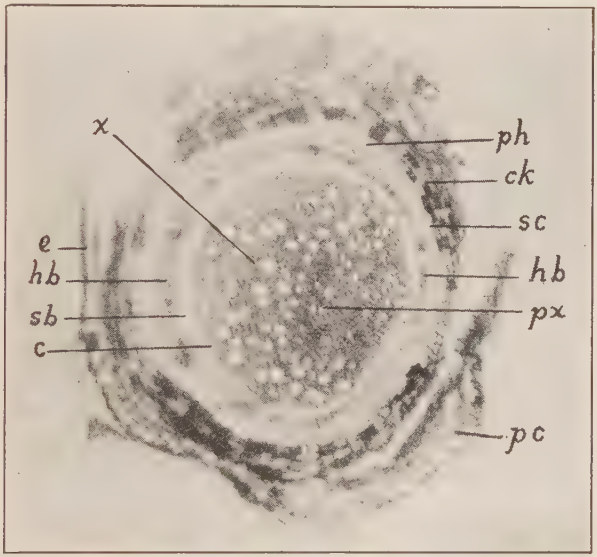

FIG. 85.—Photomicrograph of a transverse section of a California Privet root made about 1½ inches above the root tip and showing transition structure. The epidermis (*e*), primary cortex (*pc*) and endodermis are in the process of sluffing off, since cork (*ck*) has been laid down by the cork cambium (*ph*) directly beneath the endodermis. The cork cambium has also formed several layers of secondary cortex (*sc*) on its inner face. The protophloem represented largely by hard bast (*hb*) has been pushed out, while a small amount of secondary phloem represented by soft bast (*sb*) has been deposited beneath it by the cambium (*c*) which now is nearly circular in aspect. The protoxylem (*px*) has been pushed into the center by the encroaching secondary xylem (*x*) which has been laid down by the cambium on its inner face. Highly magnified.

5. *Pericambium*, of a layer of actively growing meristematic cells, which has the power of producing lateral rootlets.

6. *Radial fibro-vascular bundle* of five xylem arms alternating with as many phloem patches. Note the narrow spiral tracheæ in the xylem patches.

7. Pith, a small central zone of parenchyma.

The section you have just studied illustrated in general the appearance of any Dicotyl root of primary growth.

B. Mount permanently another cross section cut through the same root a short distance above the first.

Note that this is somewhat larger in diameter. Observe the root hairs starting from the epidermis; a broad cortex; a large clear and

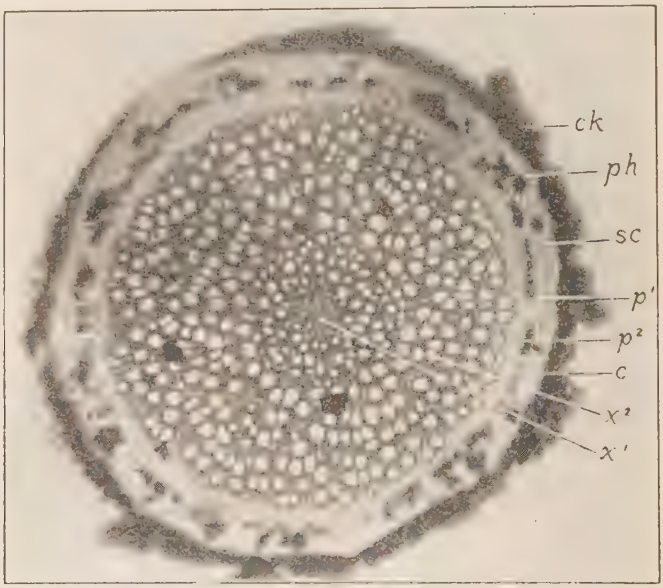

FIG. 86.—Transverse section of California Privet root made about an inch and a half above the section shown in Fig. 85 and showing early secondary structure. Note that epidermis, primary cortex and endodermis have completely disappeared. Cork (*ck*); phellogen (*ph*); secondary cortex (*sc*); protophloem (*p'*); secondary phloem (p^2); cambium (*c*); secondary xylem (x^2) and protoxylem (*x'*). (Photomicrograph.)

open looking endodermis; then pericambium; next, a central patch of xylem showing a faint pentarch relation. Pushed out are five phloem tracts. Each of these is composed of a mass of protophloem (first formed phloem). On the inner face of each phloem mass may be seen intrafascicular cambium. At the outer end of each xylem tract there has been cut off a patch of fine cambial cells (interfascicular cambium) which becomes joined to the intrafascicular cambium

to develop secondary phloem on the outer surface and secondary xylem on the inner face.

C. Mount permanently a third T. S. cut through the same root a short distance above the second. Note that this is still larger in

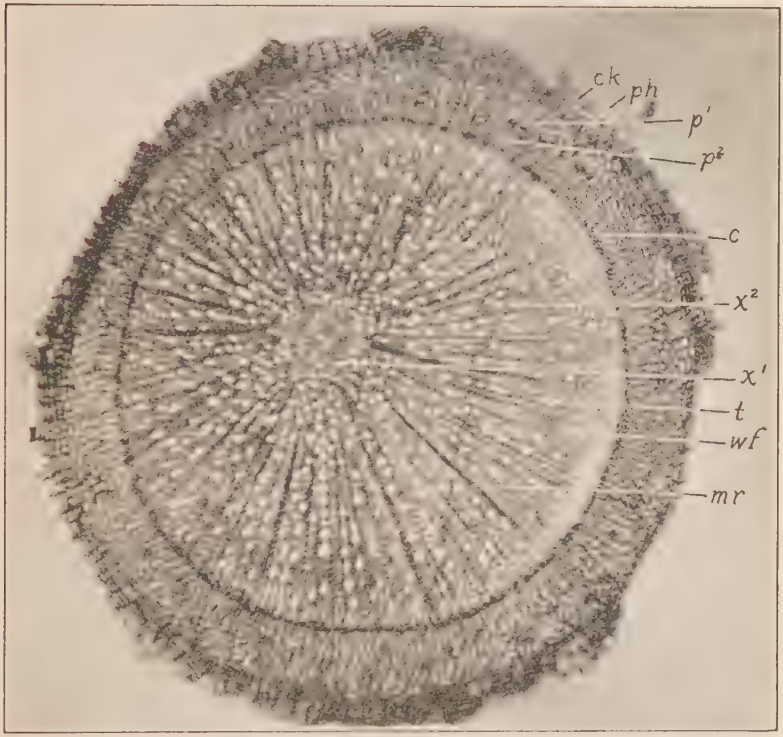

FIG. 87.—Photomicrograph of a transverse section of an old portion of California Privet root, showing completed secondary development. Note the prominent medullary rays (*mr*); cork (*ck*); phellogen (*ph*); secondary cortex (between *ph* and *p'*); protophloem (*p'*); secondary phloem (p^2); cambium (*c*); secondary xylem (x^2); tracheæ (*t*); wood fibers (*wf*); and protoxylem (*x'*).

diameter than the second. The pericambium has already divided into an inner and an outer layer. The outer layer has become the cork cambium, cutting off the cork on its outer face beneath the endodermis. Cork, being an impermeable barrier to water, has prevented the nourishing sap from percolating through to the endodermis, cor-

tex and epidermis. These regions have consequently begun to sluff off. Note that the cambium has begun to spread out into the form of a ring. More secondary xylem has been formed on its inner face and additional secondary phloem has appeared on its outer face (Fig. 85).

D. Make a permanent mount of a fourth cross section cut through the same root some distance above the third. Note that the epidermis, primary cortex and endodermis have completely peeled off. Cork is found as the external bounding layer and underneath it, cork cambium. This cork cambium has developed secondary cortex on its inner face. The cambium has assumed a circular aspect. Just beneath the secondary cortex will be found flattened patches of protophloem, and beneath these secondary phloem masses have been formed through the activity of the cambium. The cambium has developed new or secondary xylem on its inner face which has pushed the first formed or protoxylem toward the center of the root. The pith has disappeared and its place is taken by protoxylem (Figs. 86 and 87).

Abnormal Structure of Dicotyl Roots.—In certain Dicotyl roots as the Beet, Jalap, Pareira, and Poke, after the normal bundle system has been formed, there then develop successive circles of cambiums in the cortex outside of these bundles. Each of these cuts off phloem on its outer face and xylem on its inner face, thus producing concentric series of open collateral bundles.

Histology of a Dicotyl Tuberous Root (Aconitum).—A transverse section made through the tuberous root of *Aconitum Napellus* near its middle shows a cork region of one or more layers of blackish or brownish cells; a broad cortex of two regions, viz.: an outer narrower and an inner broader zone. The narrower zone consists of from eight to fifteen layers of cortical parenchyma cells, interspersed among which are numerous irregular-shaped stone cells. Separating this zone from the broader one is an endodermis of a single layer of tangentially elongated endodermal cells. The broader zone consists of about twenty layers of parenchyma cells. Stone cells may occur in this zone directly under the endodermis. Next, a five- to eight-angled cambium, within the angles of which and frequently scattered along the entire cambial line occur collateral fibro-vascular

bundles. In the center is found a broad, five- to eight-rayed pith composed of parenchyma cells. The parenchyma cells of the cortical regions and pith contain single or two- to five-compound starch grains.

Root Branching.—The branches of roots are formed by the pericycle. The cells of this region adjacent to the protoxylem undergo division by laying down tangential walls forming a mass of meristem. This meristem develops a root tip which pushes its way out laterally through the tissues of the primary root. In its passage outward, enzymes are secreted by its cells which dissolve the tissues in its path, the root growing into the cavity thereby formed. The first branches of a root are termed *secondary roots*. These may give rise to branch roots and those to further branches by the same method.

ROOT TUBERCLES

The roots of plants of the Bean and Bayberry families as well as some species of the Birthwort family and of the Alders, Cycads, Spruces, etc. are characterized by the appearance upon them of nodule-like swellings called *root tubercles*.

Leguminous Tubercles.—In the case of the members of the Bean family (*Leguminosæ*), the causative factor is a species of bacteria named *Pseudomonas radicicola*. This is a motile rod-shaped organism which appears widely distributed in soils. It is apparently attracted to the root-hairs of leguminous plants by a chemotactic influence probably due to the secretions poured out by these structures. A number of these organisms penetrate the walls of the root-hairs by enzymic action. Upon entering the hairs they form *bacterial tubes* which branch and rebranch and extend into the middle cortex cells carrying the bacteria with them. Within the cortex cells the organisms multiply rapidly producing nest-like aggregations. Their presence here stimulates the rapid multiplication of the parenchyma cells with the consequent formation of nodules or tubercles. Under oil-immersion magnification these bacteria are often found to exhibit variously shaped forms called *bacterioids*. They remain within the cells of the middle cortex region breaking down the starch and sugar present into simpler compounds. In doing this the pseudomonas obtains the energy required to "fix"

the free atmospheric nitrogen. This process is called "*fixation of atmospheric nitrogen*" and consists of uniting the free nitrogen of the air with some other elements to form a nitrogenous compound. This is assimilated into its own body.

The bacteria gradually swell up into *zoöglœa* masses, until finally their bodies break down into soluble nitrogenous substances which are partly absorbed and assimilated and partly stored as reserve nitrogenous food by the green leguminous plant.

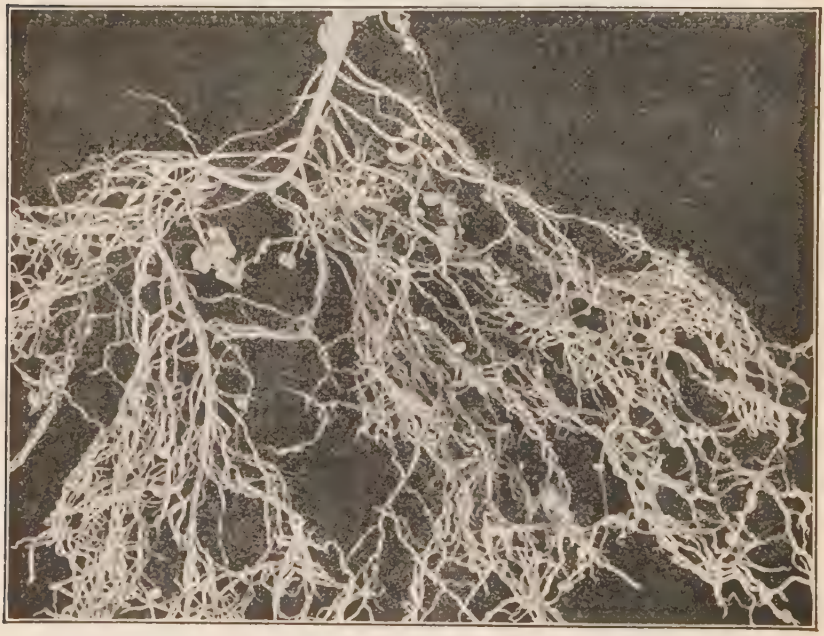

FIG. 88.—Root system of a legume showing tubercles. (*Marshall.*)

Upon the decay of the leguminous roots and their bacteria in the soil, the nitrogenous compounds are set free and are ready to be decomposed by various soil organisms into the various decomposition products, including amino-acids and ammonia.

In the modern rotation of crops, plant growers plough under the leguminous crops or their nodule-producing roots which decay and enrich the soil with ample nitrogenous material to supply the next

FIG. 89.—*Pseudomonas radicicola.* 1, From *Melilotus alba;* 2 and 3, from *Medicago sativa;* from *Vicia villosa.* (*Marshall, after Harrison and Barlow from Lipman.*)

FIG. 90.—Tubercular clusters on underground stem and roots of a Bayberry, *Myrica Macfarlanei,* observed by the author at North Wildwood, N. J., Jan. 31, 1915.

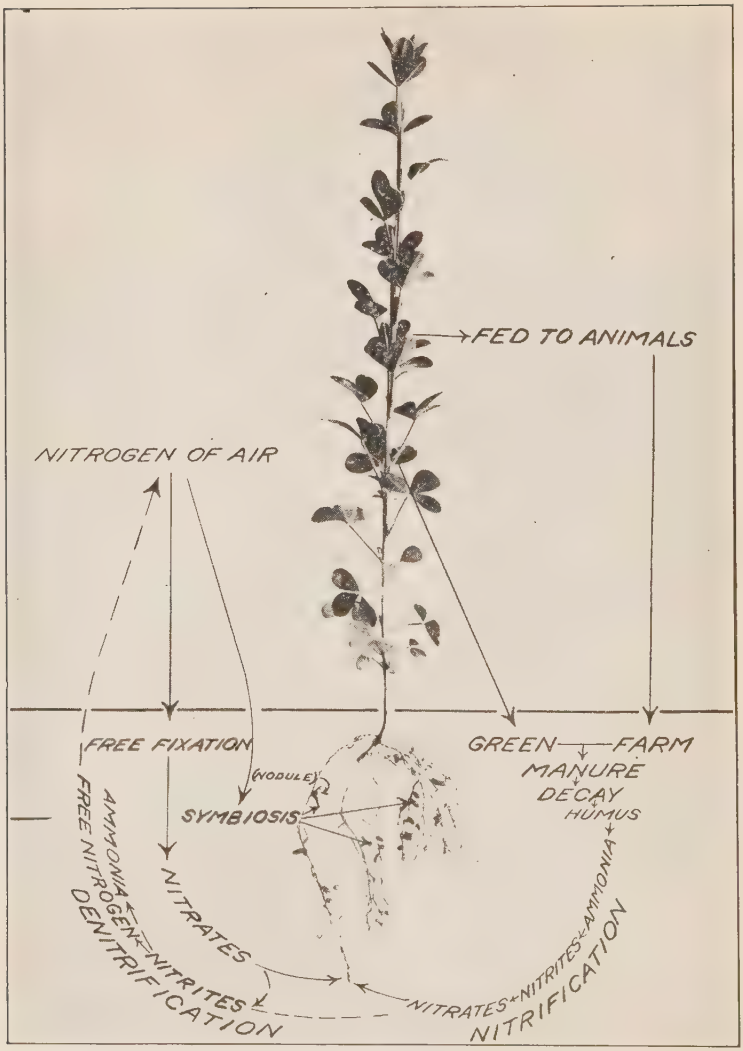

FIG. 91.—Nitrogen cycle in the life of alfalfa, a leguminous plant. (*From Brownell's General Science.*)

season's crop of nitrogen-consuming plants, such as cereals, cabbage, potatoes, etc.

Many strains of *Pseudomonas radicola* exist, one for every kind of leguminous crop. Cultures of many of these, such as "Nitro-Germ," etc. are now obtainable from the drug trade.

Myrica Tubercles.—The writer has found tubercles on *Myrica cerifera*, *Myrica Caroliniensis* and *Myrica Macfarlanei* seedling primary roots of 5 to 6 months' growth, and from thence onward on the secondary roots inserted on the hypocotyl axis, on nearly all the adventitious roots of subterranean branches and on the subterranean branches of *Myrica cerifera*, *M. Caroliniensis*, *M. Gale*, *M. Macfarlanei*, and *Comptonia asplenifolia*. The inciting organism has been isolated by him in pure culture according to Koch's postulates and named *Actinomyces Myricarum* Youngken.

The tubercles occur either singly, as is frequently the case on subterranean branches, in small groups the size of a pea, or in larger coralloid loose or compact clusters which frequently attain the size of a black walnut. Each tubercle is a short, cylindrical, blunt-ended, root-like structure which branches di- or trichotomously after attaining a certain length. The branches frequently rebranch at their tips which grow out into long thread-like structures from 1–3 cm. in length that may also branch and become entwined about the roots of other plants. The color of the youngest tubercles is a pinkish-gray brown. As the tubercles become older their color changes to brown. dark-brown and even black.

THE NITROGEN CYCLE

Living plants make use of nitrogen in the form of nitrates found in the soil and water. The nitrates are absorbed by the plant and split up within its cells into the component elements, the nitrogen of which is linked with some other simple elements there present including carbon, hydrogen, oxygen, sulphur and sometimes phosphorus to form proteins. Animals eat the plants and part of the proteins are digested by them and excreted as urea, uric acid and hippuric acid. These products are later decomposed by bacteria (*micrococcus ureæ*, etc.) to form ammonia. The remainder of the proteins are assimilated and stored in the growing animal cells.

When the animals die their bodies decay and the protein or nitrogenous compounds are split into decomposition products (peptones, amino-acids, ammonia) of which ammonia is the final end product.

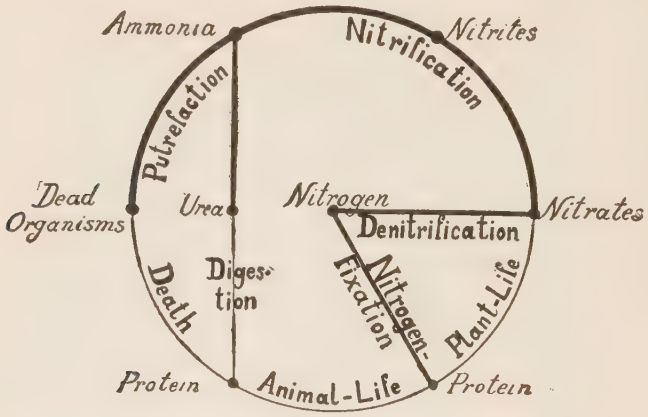

FIG. 92.—Nitrogen cycle. (*Marshall.*)

FIG. 93.

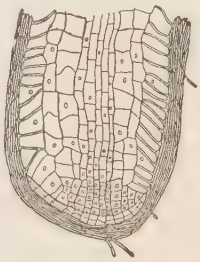

FIG. 94.

FIG. 93.—Mycorhizal mantle on root of hickory (*Carya ovata*) in cross section.
FIG. 94.—Longitudinal section through root tip of an oak (*quercus*) covered by an ectotrophic mycorhiza. (*Gager, after W. B. McDougall.*)

The soil contains **nitrifying bacteria.** Of these the *Nitrosomonas* and *Nitrosococcus* oxidize ammonia to nitrous acid and nitrites. Another nitrifying organism, the *Nitrobacter* oxidizes nitrous acid and nitrites to nitrates, thus completing the cycle.

MYCORHIZA

The roots of many plants, especially those growing in humus, are associated with fungal hyphæ which form a weft over their surface, as in the case of the beech, etc., when this weft is called an *ectotrophic mycorhiza*, or the surrounding hyphæ may penetrate into the cells of the roots, as in many plants of the Heath family, when the association is termed an *endotrophic mycorhiza*.

There are a number of plants, particularly non-green seed plants, which cannot thrive without the mycorhizæ with which their roots are normally associated and die when transplanted to soil not containing them. Mycorhizæ assist the roots to absorb nutrient materials from the soil.

CHAPTER IX

THE BUD

Buds are short young shoots with rudimentary leaves compactly arranged upon them.

The *plumule* represents the first bud on the initial stem or caulicle.

Scaly buds are such as have their outer leaf rudiments transformed into scales; these are often coated with a waxy or resinous substance without and a downy lining within to protect them from sudden changes in climate. Buds of this character are common among shrubs and trees of temperate regions.

Naked buds are those which are devoid of protective scales. They are common to herbaceous plants.

Classification of Buds According to Development.—1. A *leaf bud* is a young shortened shoot bearing a number of small leaves. It is capable of elongating into a branch which bears leaves.

2. A *flower bud* is a rudimentary shoot bearing one or more concealed and unexpanded young flowers.

3. A *mixed bud* is a young shoot bearing concealed, unexpanded leaves and flowers.

Classification of Buds According to Position on the Stem.—1. A *terminal bud* is one which is located on the end of a stem (shoot). It is capable of elongating into a shoot which bears leaves or both leaves and flowers.

2. An *axillary* or *lateral bud* is one which arises in the leaf axil. It is capable of giving rise to a side branch or to a flower. Occasionally axillary buds do not develop and are then called *dormant buds*.

3. An *adventitious bud* is one which occurs on some position of the plant other than at the apex of the stem or in the axil of a leaf. Such buds may be seen developing along the veins of a Begonia leaf or along the margin of a Bryophyllum leaf after these have been planted in moist soil for several days.

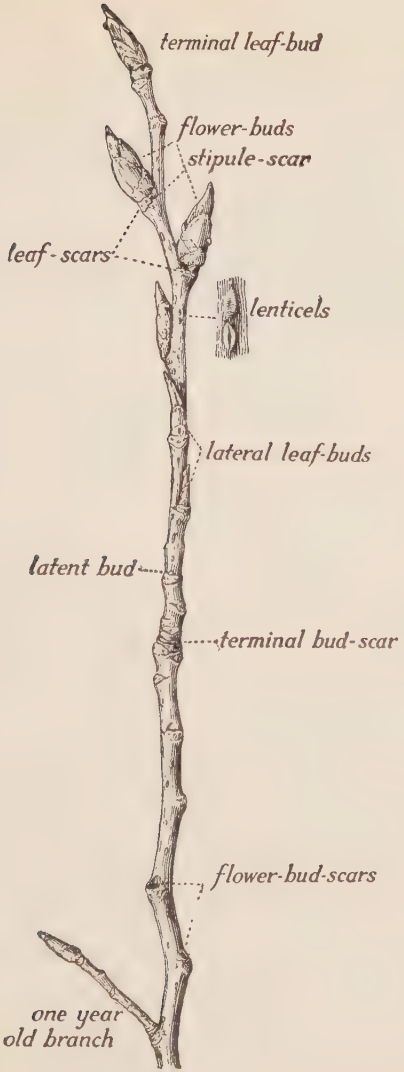

FIG. 95.—Cottonwood twig, two years old. (*From Robbins after Longyear.*)

4. An *accessory bud* is an extra bud which forms in or near the leaf axil. These may be seen on the young stems of the Red Maple.

5. A *sub-petiolar bud* is one arising beneath the basal part of the petiole or leaf stalk, so that when the leaf falls off the bud becomes exposed, as in the Buttonwoods.

Classification of Buds According to Their Arrangement on the Stem.

1. When a single bud is found at each joint or *node* of a stem, the buds are said to be alternate.

2. When two buds are found at a node they are *opposite.*

3. When several buds occur at a node they are *whorled.*

CHAPTER X

THE STEM

The stem is that part of the plant axis which bears leaves or modifications of leaves and its branches are usually arranged with mathematical regularity.

Stems usually grow toward the light and so are positively heliotropic.

The functions of a stem are to bear leaves or branches, connect roots with leaves, and conduct sap.

When the stem rises above ground and is apparent, the plant is said to be *caulescent.*

When no stem is visible, but only flowers or leaf stalks, the plant is said to be *acaulescent.*

Stems vary in size from scarcely $\frac{1}{25}$ inch in length, as in certain mosses, to a remarkable height of 400 feet or more. The giant Sequoia of California attains the height of 420 feet and has a trunk diameter at its base of between 25 and 30 feet. Some of the Eucalyptus trees of Australia and Tasmania are reported to attain the height of 500 feet.

Nodes and Internodes.—The nodes are the joints of stems. They represent the parts of the stem from which leaves or branches arise. Internodes are the parts of stems between nodes.

Direction of Stem Growth.—Generally the growth of the stem is upright or *erect.* Very frequently it may be:

Ascending, or rising obliquely upward. Example: Saw Palmetto.

Reclining, or at first erect but afterward bending over and trailing upon the ground. Example: Raspberry.

Procumbent, lying wholly upon the ground. Example: Pipsissewa.

Decumbent, when the stem trails and the apex curves upward. Examples: Vines of the *Cucurbitaceæ* or Gourd family.

Repent, creeping upon the ground and rooting at the nodes, as the Strawberry.

Stem Elongation.—At the tip of the stem there is found a group of very actively dividing cells (*primordial meristem*) which is the growing point of the stem. All the tissues of the stem are derived from the cells of the growing point whose activity gives rise in time to three generative regions which are from without, inward:

1. *Dermatogen* or *protoderm* forming epidermis;

2. *Periblem* or *ground meristem* forming the cortex, pericycle, and pith.

3. *Plerome* or *procambium* forming the fibro-vascular elements.

Duration of Stems.

Annual, the stem of an herb whose life terminates with the season. Example: Corn.

Biennial, where the stem is formed during the first year and dies during the second year. Example: Burdock.

Perennial, when the stem lives for many years. Example: Oak.

Forms of Stems.—The following adjectives appear in pharmacognostic and botanical literature in relation to the form of stems and in some instances other plant organs: *Cylindraceous* or cylinder-shaped; *subcylindrical* or somewhat cylinder-shaped; *terete* or circular in cross section; *compressed* or pressed together above and below or laterally; *triquetrous* or three-angled, *quadrangular*, or four-angled; *alate* or winged; *exfoliating* or shedding cork in layers; *obconical*, or having the shape of an inverted cone; *flexuous* or bent; *tortuous* or twisted; *truncate*, or ending abruptly as if cut across at the summit.

Stem Modifications.

Twining stems are those which coil spirally around a support as the stems of the Hop, Bittersweet, Dodder, etc.

Tendriliform stems are those which undergo thread-like modification and become sensitive to contact of a side branch or other object, coiling around it, as in Passion flower, Grape, Squash, etc.

Spines are formed by the checking and hardening of a branch that may then become defensive as in hawthorn, honey locust, etc.

Aerial tuberous stems are those in which one or more internodes enlarge above ground and store reserve food, as in pseudobulbs of orchids.

Subterranean tuberous stems are those in which an underground stem or branch enlarges as a food-storing center: (*a*) annual type,

tuber, as in potato, etc., corm, as in crocus, etc.; (*b*) perennial type, bulbs as in lily (scaly) and onion or hyacinth (tunicated).

Phylloid stems or *phylloclades* are green, flat, leaf-like stems in which flattening branch expansion has occurred, as in *Asparagus*, *Ruscus*, etc.

Cactoid stems are those in which reduced condensed branches or stems become swollen for water (and food) storage, as in Cacti, *Euphorbia* species, etc.

Above-ground or Aerial Stems.—A *twining* stem winds around a support, as the stem of a bean or Morning Glory.

A *culm* is a jointed stem of the Grasses and Sedges.

A *climbing* or scandent stem grows upward by attaching itself to some support by means of aerial rootlets, tendrils or petioles. Examples: Ivy, Grape, etc.

The *scape* is a stem rising from the ground and bearing flowers but no leaves, as the dandelion, violet, or blood root.

A *tendril* is a modification of some special organ, as of a leaf stipule or branch, capable of coiling spirally and used by a plant in climbing. The tendrils of the Grape Vine are modified inflorescence branches, those of Sarsaparilla are modified stipules and those of the Pea are modified leaflets.

A *spine* or *thorn* is the indurated termination of a stem tapering to a point, as the thorns of the Honey Locust.

Prickles are outgrowths of the epidermis and cortex and are seen on the stems of the roses, greenbriers, etc.

A *stolon* or *runner* is a prostrate branch, the end of which, on coming in contact with the soil, takes root, so giving rise to a new plant. Examples: Currant and Raspberry.

A *bulbel* or *bulbil* is a small, bulb-shaped, young aerial shoot which serves as an organ of vegetative multiplication by falling off the stem and developing into a new plant. The Garlic and Tiger Lily are good examples of plants which produce bulbels.

An *herbaceous stem* is one which is soft in texture and readily broken. Example: Lily-of-the-Valley.

An *undershrub* or *suffruticose* stem is a stem of small size and woody only at the base. Examples: Bittersweet, Thyme, etc.

A *shrubby* or *fruticose* stem is a woody stem larger than the preceding and freely branching near the ground. Example: Lilac, etc.

A *trunk* is the woody main stem of a tree.

Herb, Shrub and Tree

An **herb** is a plant whose stem does not become woody and permanent, but usually dies, at least down to the ground, after flowering.

Fig. 96.—An elm tree in summer and winter. To illustrate alike the deliquescent habit of branching and the deciduous nature of this tree (dropping its leaves in autumn and developing new ones in the spring.) (*Atwood.*)

Herbs are either annual, biennial or perennial (see p. 163). When a perennial herb possesses an aerial stem which develops leaves that persist on the stem over winter, as the Partridge Berry, it is called an *evergreen herb.*

A **tree** is a perennial woody plant of considerable size, attaining a height of 15 or more feet, and having as the above-ground parts a trunk and a crown of leafy branches.

There are two plans of branching in trees. When the trunk, or main stem, extends vertically upward to the tip, as it does in the pines, junipers, spruces and other conical trees, the type of branching is called *excurrent;* when it divides into several more or less equal divisions as in the elm and other spreading trees, it is said to be *deliquescent.* The deliquescent plan is the more common one among our deciduous trees.

A **shrub** is a perennial woody plant of smaller stature than a tree whose stem is relatively short and usually branches near the ground. Examples: Viburnum, Elder, Buchu, Krameria, etc.

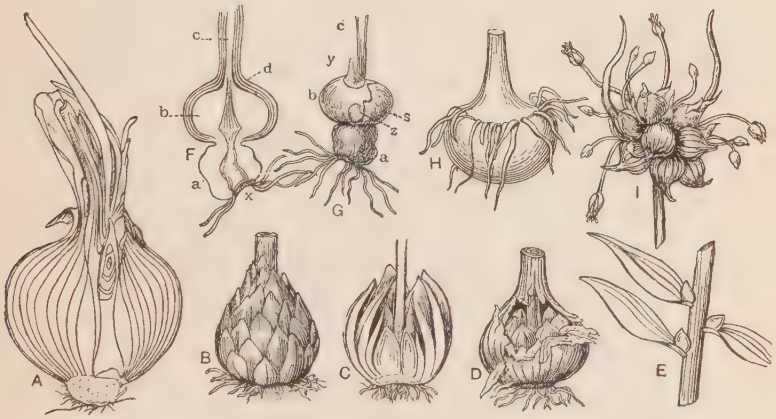

FIG. 97.—A, tunicate bulb of Onion (*Allium Cepa*), in longitudinal section; B, Scaly bulb of Canada Lily (*Lilium canadense*); C, Same as B, but in longitudinal section; D, Bulb of Garlic (*Allium sativum*) with portion of the scales cut away so as to enclose the young bulbs within; E, Portion of stem of Tiger Lily (*Lilium tigrinum*), showing bulbils in the axils of the leaves; G, Corm of Crocus showing a terminal and one lateral bud. The horizontal lines represent the scars of the few scales that have been removed. At the base is the remnant of last year's corm. The various buds will develop into new corms. F, Vertical section of a similar corm. H, flat corm of Cyclamen; I, Bulblets at the apex of a flower stalk of the Onion. (*After Gager*).

Underground or **Subterranean Stems.**—A **rhizome** is a creeping underground stem, more or less scaly, sending off roots from its lower surface and stems or leaves from its upper. The rhizome grows horizontally, vertically or obliquely, bearing a terminal bud at its tip. Its upper surface is marked with the scars of the bases of

aerial stems or leaves of previous years. Examples: Triticum, Rhubarb, etc.

The **tuber** is a short and excessively thickened underground stem, borne usually at the end of a slender, creeping branch, and having numerous eyes or buds. Example: Tubers of the Potato.

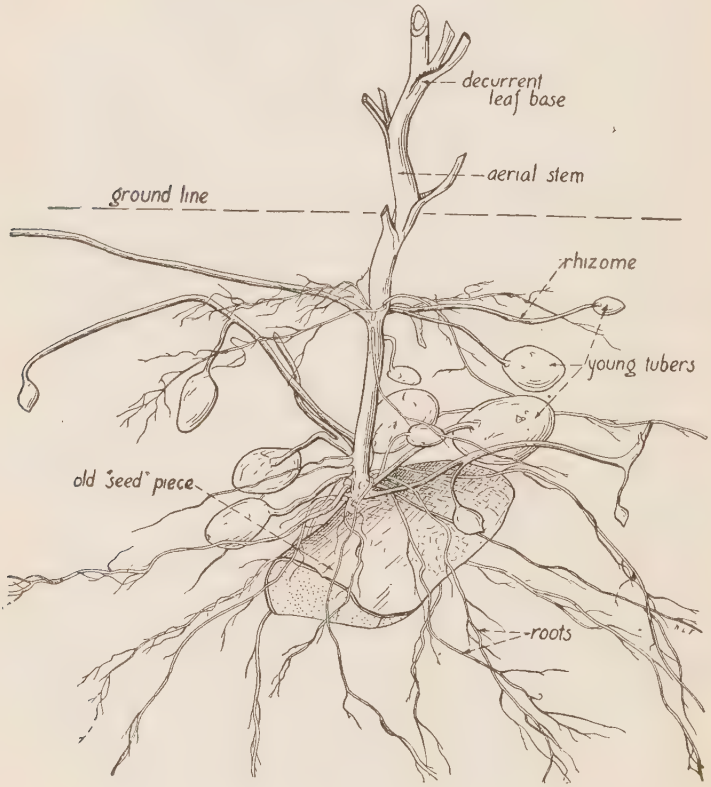

FIG. 98.—Portion of a sprouting potato tuber. (*After Robbins.*)

The **corm** is an underground stem excessively thickened and solid and characterized by the production of buds from the center of the upper surface and rootlets from the lower surface. Examples: Colchicum, Jack-in-the-Pulpit, Crocus, etc.

A **bulb** is a very short underground stem invested by fleshy scales which represent storage leaves. It produces rootlets from its lower face and leaves and flower from its upper.

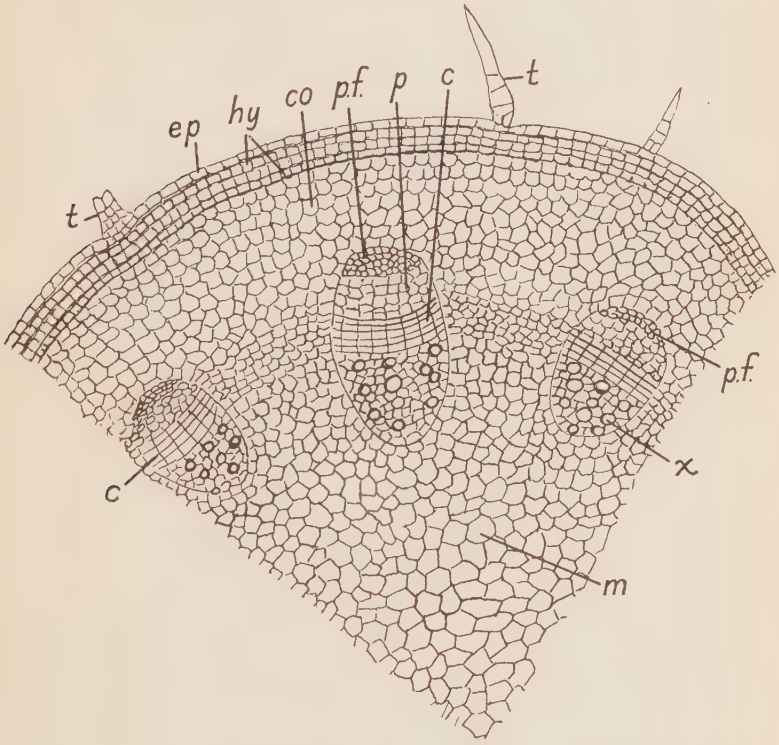

FIG. 99.—Sunflower stem. Representative portion of a transverse section cut through upper, young part of stem. *ep*, epidermis bearing trichomes (*t*); *hy*, hypodermis; *co*, primary cortex; *pf*, pericyclic fibers; *p*, protophloem of primary fibrovascular bundle; *c*, intrafascicular cambium of bundle; *x*, protoxylem of bundle; *m*, pith or medulla. All of the tissue between each two bundles is a primary medullary ray. Greatly enlarged.

Tunicated bulbs are completely covered by broad scales which form concentric coatings. Examples: Onion, Squill, Daffodil.

Scaly bulbs have narrow imbricated scales, the outer ones not enclosing the inner. Example: Lily.

Exogenous and Endogenous Stems.—*Exogenous stems* are typical of Gymnosperms and Dicotyledons and can increase materially in thickness due to the presence of a cambium. Such stems show differentiation into an outer bark cylinder and an inner or wood cylinder. Between the bark and the wood cylinders is a cambium.

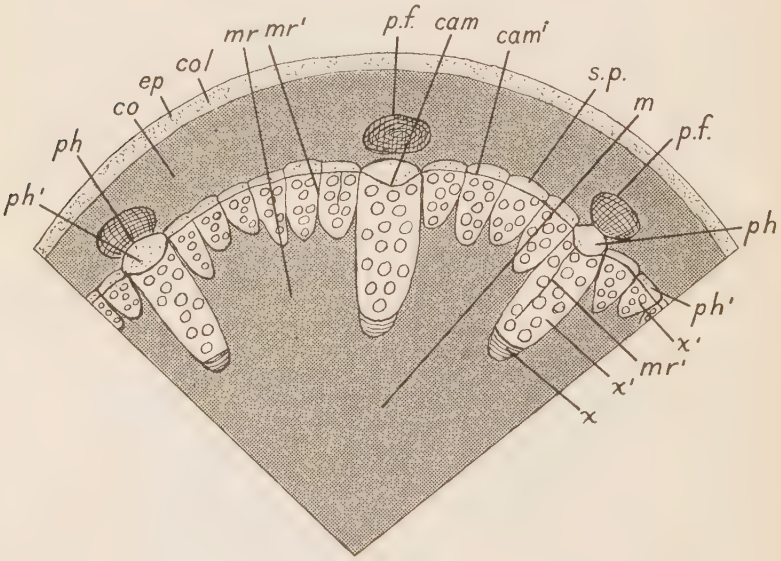

FIG. 100.—Diagram of a representative portion of a transverse section cut through an old part of the Sunflower stem. *ep*, epidermis; *col*, collenchyma; *co*, cortex; *p.f.*, pericyclic fibers in pericycle; *ph*,' protophloem; *ph*, secondary phloem; *cam*, intrafascicular cambium; *cam*,' interfascicular cambium; *x*, protoxylem; *x'*, secondary xylem; *mr*, primary medullary ray; *mr'* secondary medullary ray; *m*, pith. The three longest bundles represent primary bundles which have been broadened by the cambium adding secondary phloem outwardly and secondary xylem inwardly. The smaller bundles represent secondary bundles, each consisting of secondary phloem, cambium and secondary xylem.

Endogenous stems are typical of most Monocotyledons and cannot increase materially in thickness due to the absence of cambium. The limited increase in diameter that does take place is due to the enlargement of the cells of the primary tissues. Such stems show no differentiation into bark and wood regions.

Histology of Annual Dicotyl Stem.—Excellent stem material of an annual dicotyledon for the study of the stems of this type is to be found in the sunflower. Transverse sections cut through the upper, thin, younger portion of this stem, present the following structures: (In both annual and perennial dicotyledonous stems, endodermis and pericycle are rarely distinguishable from the cortex, except for the knowledge of their relative position, since each has become so similar to the cortex through passage of food, etc.)

1. **Epidermis,** a single layer of somewhat flattened cells whose outer walls are cutinized. Some of the cells show outgrowths as hairs. Stomata also occur.

2. **Primary Cortex,** composed of two zones: an outer region of several layers of narrow, thick-walled cells (hypodermis) and a broad zone of larger, thin-walled cortical parenchyma cells, many of which contain chloroplasts.

3. The innermost layer of cells of the cortex is called the **endodermis.** (Not generally distinguishable.)

4. **Pericycle** (Pericambium). Not generally distinguishable in most dicotyl stems but showing early formation of groups of fibers in sunflower stems.

5. **Primary fibro-vascular bundles** of open collateral type arranged in a circle with primary medullary rays between the bundles. Each bundle shows an outer *protophloem,* a *cambium* called *intrafascicular cambium,* because it is within the bundle, and an inner *protoxylem.*

6. **Pith,** composed of parenchyma cells.

If a series of additional cross sections are now cut at different descending levels along the Sunflower stem until the old part of the stem near the ground is reached, and these be examined microscopically, it will be noted that some secondary changes have taken place which explain the gradual increase in thickness of this stem as the base is approached. One of the first of these changes incident to secondary growth is that observed in the cells of the primary medullary rays between the *intrafascicular cambia* of the various bundles. These lay down tangential walls to form *interfascicular cambia* or cambiums between the bundles. When this process is completed, a continuous *cambium ring* is formed.

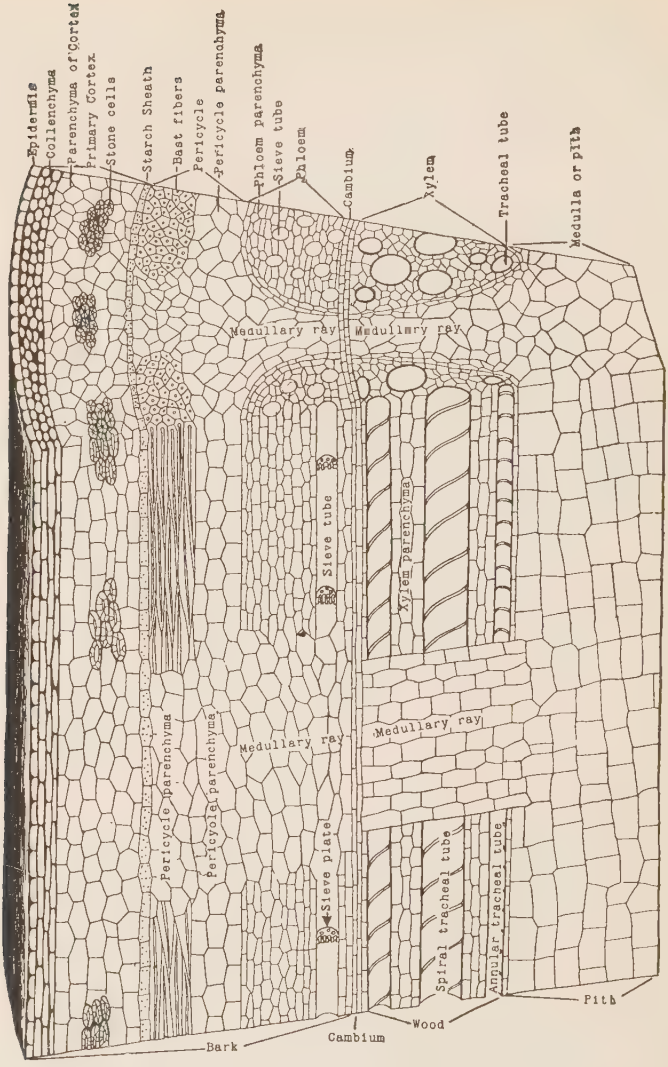

FIG. 101.—A diagram to show the character of the tissues and their disposition in a young stem of the typical dicotyledon type. (*From Stevens.*)

The cambium ring adds more xylem elements called *secondary xylem* on its inner face and more phloem elements called *secondary*

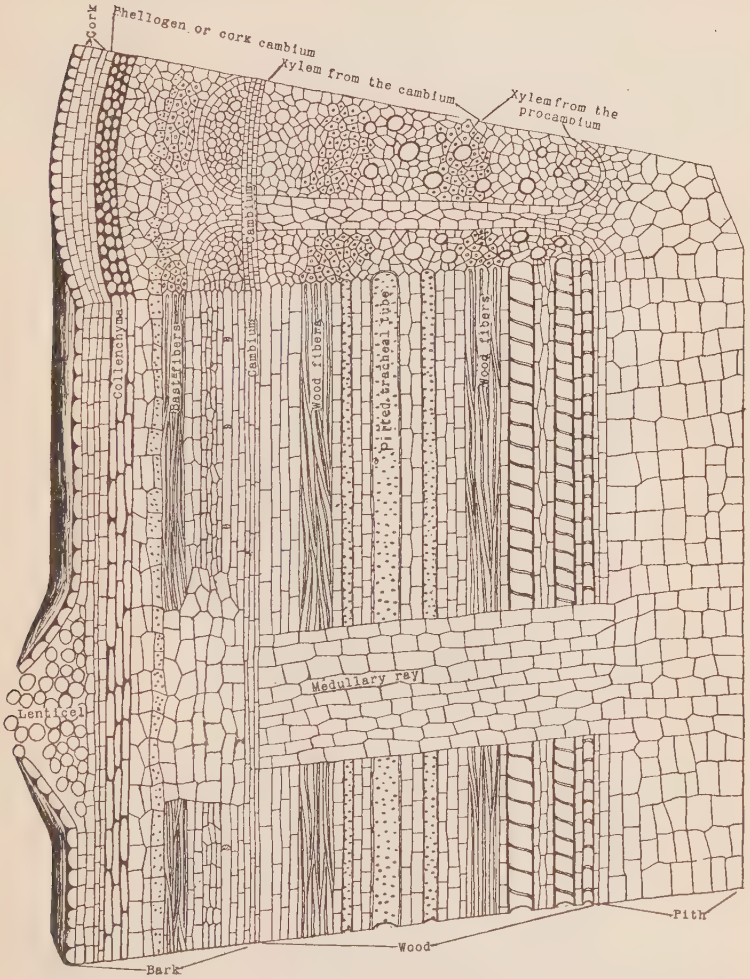

FIG. 102.—Diagram similar to the preceding but representing a later stage and showing the tissues formed by the cambium. (*From Stevens.*)

phloem on its outer face. As it cuts off sieve tubes and companion cells outwardly and tracheæ and wood fibers inwardly all along the

line it also cuts off here and there a medullary ray cell on each of its faces. It will be noted that more secondary xylem is added than secondary phloem. The result of the activity of the cambium ring is the deepening of the primary bundles and the primary medullary rays, the appearance of new or secondary bundles (which are smaller than the primary bundles) in the primary medullary rays and the appearance of narrow secondary medullary rays between the secondary bundles as well as inside of the deepened primary bundles.

As secondary increase progresses, it will be noted that certain cells in widely separated regions of the pericycle begin to divide

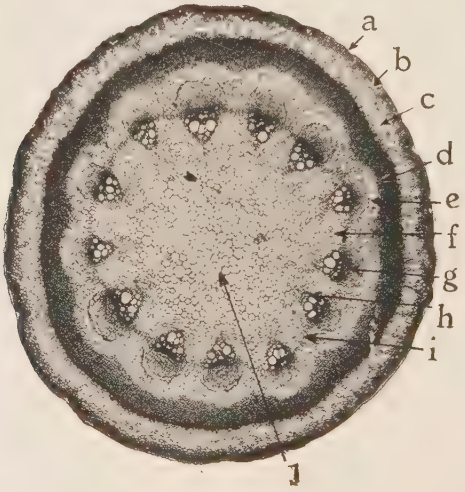

FIG. 103.—Photomicrograph of cross-section of stem of *Aristolochia sipho*, where cambial activity is just beginning. *a*, Epidermis; *b*, collenchyma; *c*, thin-walled parenchyma of the cortex, the innermost cell layer of which is the starch sheath or endodermis; *d*, sclerenchyma ring of the pericycle; *e*, thin-walled parenchyma of the pericycle; *f*, primary medullary-ray; *g*, phloem; *h*, xylem; *i*, interfascicular cambium; *j*, medulla or pith. × 20. (*From Stevens.*)

rapidly producing groups of thick-walled *pericyclic fibers* here and there within the pericycle but chiefly outside of the protophloem of the larger or primary bundles.

Growth of Perennial Dicotyl Stem and Its Histology.—A perennial dicotyl stem, in the first year of its growth, does not differ in structure from an annual. By the close of the year a cork cambium

(phellogen) has originated beside the epidermis. In the origin of the *cork cambium*—one of two methods: (*a*) either the epidermis may divide into an outer layer of cells that remains epidermis and an inner layer of cells that becomes cork cambium, or, (*b*) the outermost layer of cortex cells underneath the epidermis becomes active after being passive for one year, and lays down walls, the inner layer becoming cork cambium, the outer becoming a layer of cork. The cork cuts off water and food supplies from the epidermis outside, and so the epidermis separates and falls off as a stringy layer. The cork cambium produces cork on its outer face and secondary cortex on its inner.

Between the bundles, certain cells of the primary medullary-rays become very active and form *interfascicular cambium* which joins the cambium of the first-formed bundles (*intrafascicular cambium*) to form a complete *cambium ring*. By the rapid multiplication of these cambial cells, new (secondary) xylem is cut off internally and new (secondary) phloem externally, pushing inward the first-formed, or *protoxylem*, and outward the first-formed, or *protophloem*, thus increasing the diameter of the stem. The primary medullary-rays are deepened. Cambium may also give rise to secondary medullary-rays.

Sometimes, as in Grape Vines, Honeysuckles, Hickories and Asclepias, instead of cork cambium arising from the outer cortex cells, it may arise at any point in the cortex. It is the origin of cork cambium at varying depths that causes extensive sheets of tissue to separate off. This dead tissue has been termed *borke* by the German botanists. That is what gives the stringy appearance to the stems of climbers.

At close of first year in a *Perennial Dicotyl Stem* we note:

1. Epidermis—development of dermatogen—in process of peeling off, later on entirely absent.
2. Cork tissue.
3. Cork cambium or phellogen.
4. Sometimes zone of thin-walled cells containing chloroplasts cut off by cork cambium on inner face and known as *phelloderm* or secondary cortex.
5. Primary cortex—in perennials, stem cells of cortex may undergo modification into mucilage cells, into tannin receptacles, crystal cells, spiral cells, etc.

6. Endodermis, or innermost layer of cells of cortex, usually similar to other cortex layers in character of cells.
7. Pericycle, a parenchymatous region usually appearing similar to the cortex, but sometimes containing sclerenchyma fibers or stone cells or both.
8. Fibro-vascular bundles of open collateral type which are now arranged into a compact circle, and between which are found primary- and often secondary medullary-rays.

From without inward the following tissues make up the f.v. bundles.

Protophloem	Hard Bast—long tenacious bast fibers.
Secondary Phloem	Soft Bast—phloem cells and sieve tubes.

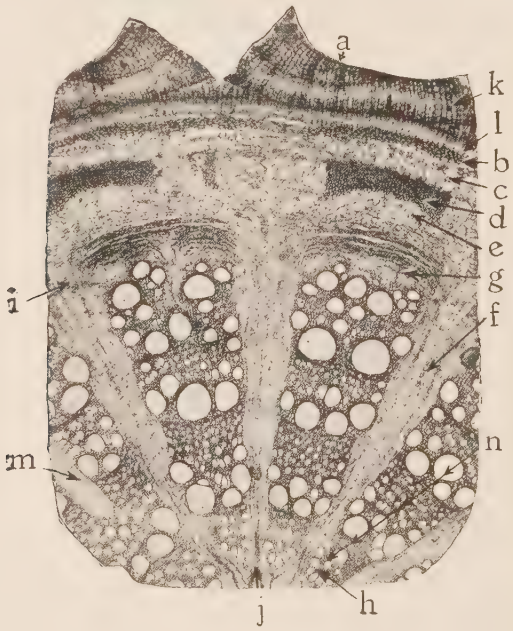

FIG. 104.—Portion of cross-section of four-year-old stem of *Aristolochia sipho*, as shown by the rings of growth in the wood. The letters are the same as in Fig. 103 but new tissues have been added by the activity of the cambium; and a cork cambium has arisen from the outermost collenchyma cells and given rise to cork. The new tissues are: *l*, cork cambium; *k*, cork; *g*, secondary phloem from the cambium, and just outside this is older crushed phloem; *n*, secondary xylem produced by the cambium; *m*, secondary medullary ray made by the cambium (notice that this does not extend to the pith). Half of the pith is shown. Notice how it has been crushed almost out of existence. Compare Figs. 103 and 104, tissue for tissue, to find out what changes the primary tissues undergo with age, and to what extent new tissues are added. Photomicrograph × 20. (*From Stevens.*)

Cambium—active layer giving rise to secondary phloem on outer and secondary xylem or inner face, and adding to depth of med. rays.
Secondary xylem—wood fibers, pitted vessels, tracheids.
Protoxylem—spiral tracheæ.

9. Pith.

EXCEPTIONAL TYPES OF DICOTYL STEMS

In a number of Dicotyledons and Gymnosperms, the secondary growth in thickness of the stem and frequently of the root differs from that which is found in the vast majority of species and so is called exceptional or anomalous.

FIG. 105. -White birch (*Betula populifolia*). Portion of a branch showing the prominent lenticels. (*Gager.*)

In stems of *Phytolacca*, etc., there first arises a ring of primary bundles with broad, loose medullary-rays. Then the stem cambium ceases its activity and, outside the bast of the bundles already formed, in the pericycle or tissue developing from it, a new cambium starts to lay down another ring of bundles in rather irregular fashion. Then, after developing a wavy ring of bundles and connecting tissue,

the cambium closes up. Still another cambium ring arises without this, and in a single season quite a number of these are found successively arranged in concentric fashion.

In *Gelsemium*, species of *Solanaceæ*, *Combretaceæ*, *Cucurbitaceæ*, etc., there arises a cambium on the inner face of the xylem which forms *internal phloem* (or *intraxylary phloem*), thus giving rise to bicollateral bundles. (See Fig. 68.)

In *Strychnos Nux Vomica*, internal phloem, exactly as in *Gelsemium*, etc. appears, but in addition *interxylary phloem* is developed. In the wood region of this plant axis the cambium starts at a certain

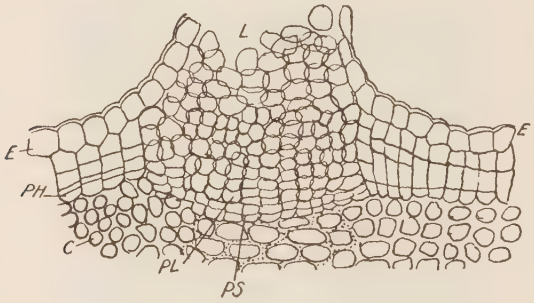

FIG. 106.—Cross-section through a lenticel of *Sambucus nigra*. *E*, Epidermis; *PH*, phellogen; *L*, loosely disposed cells of the lenticel; *PL*, cambium of the lenticel; *PS*, phelloderm; *C*, cortical parenchyma containing chlorophyll. (*From Sayre after Strasburger.*)

age to lay down patches of phloem which become wedged in between xylem tissue as interxylary phloem.

Lenticels and Their Formation.—The epidermis in a great majority of cases produces stomata, apertures, surrounded by a pair of guard cells, which function as passages for gases and watery vapor from and to the active cells of the cortex beneath.

There very early originate in the region beneath some of the stomata loosely arranged cells which are cut off by the cork cambium in certain places instead of cork. These swell up during rain and pressing outward, form fissures in the epidermis, called lenticles.

The function of lenticels is similar to that of stomata, namely, to permit of aëration of delicate cells of the cortex beneath. While

common to many plants, they are very conspicuously prominent in the birches and cherries.

Annual Thickening.—In all woody exogenous stems, such as trees and shrubs, the persistent cambium gives rise to secondary xylem thickening every spring, summer and autumn. Soon a great cylinder of xylem arises which constitutes the wood of the trunk and

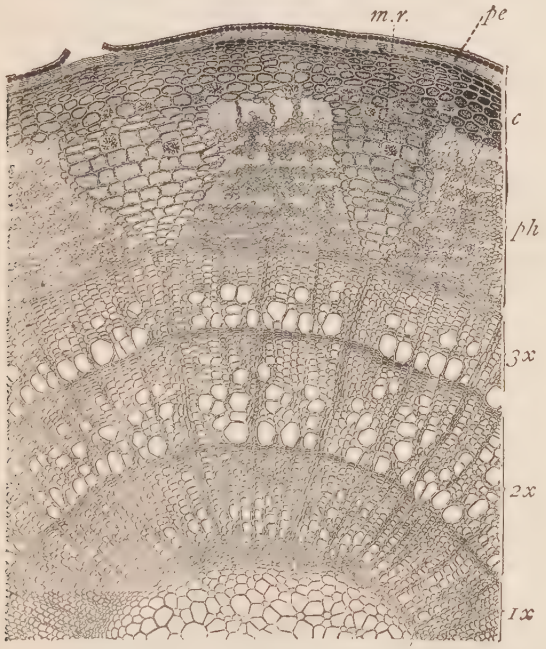

FIG. 107.—Representative portion of a transverse section of a Linden stem, 3 years old.—*1x*, *2x*, *3x*, Successive annual rings of wood. *ph*, Phloem, with bast fibers showing as lighter parts and sieve-tubes as darker parts. *c*, Cortex containing chloroplasts and rosette crystals of CaO. *m.r.*, spreading end of primary medullary ray. *pe*, periderm. (*From Small, after Kny.*)

branches. In the spring, growth is more active, and large ducts with little woody fiber are produced while in summer and autumn growth is lessened and small ducts and much mechanical woody fiber are formed. Thus the open, loosely arranged product of the spring growth abuts on the densely arranged product of the last summer and autumn growth and the sharp contrast marks the

periods of growth. To the spring, summer and autumn regions of growth of each year is given the term of **"annual ring."** By count-

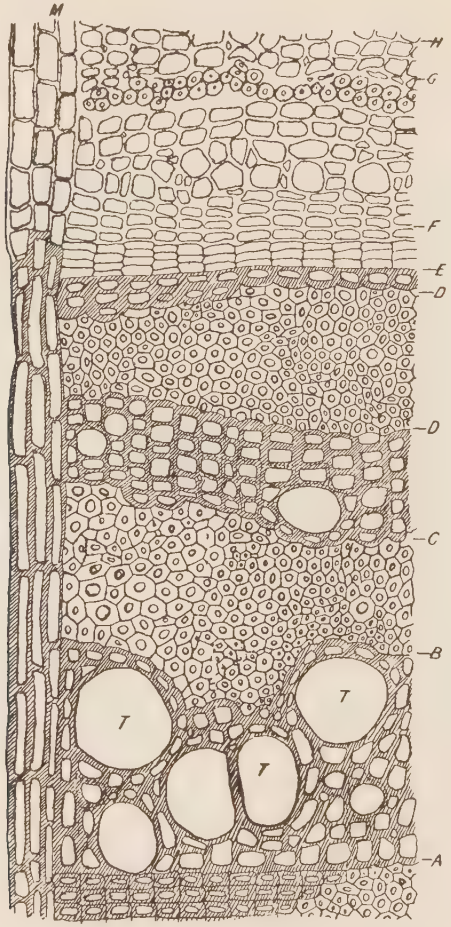

FIG. 108.—Part of a cross-section through branch of *Cytisus laburnum*. (The branch was cut from the tree at the end of October.) From *A* to *E* the last annual ring of wood; from *A* to *B* the spring growth with large tracheal tubes (*T*, *T*, *T*); between *B* and *C* and *D* and *D* are wood-fibers; between *C* and *D* and *D* and *E*, wood parenchyma; from *E* to *F*, cambium; *F* to *G*, phloem portion; *G* to *H*, cortical parenchyma; *M*, medullary ray. Below *A* the last wood-fibers and wood parenchyma formed the previous year. (*From Sayre after Haberlandt.*)

ing the number of these rings it is possible to estimate the age of the tree or branch.

Bark.—Bark is a term applied to all that portion of a woody exogenous plant axis outside of the cambium line.

In pharmacognic work, bark is divided into three zones, these from without inward being:

1. *Outer Bark* or *Cork.*
2. *Middle Bark* or *Cortical Parenchyma.*
3. *Inner Bark* or *Phloem.*

Cork.—Cork is all that tissue produced by the cork cambium on its outer face. Its walls become impregnated with a waterproof substance of a waxy character called *suberin.*

Periderm.—Periderm is a name applied to all the tissue produced by the cork cambium (*Phellogen*) externally and internally and includes the cork cambium itself. This term appears often in pharmacognic and materia medica texts.

Phelloderm.—Phelloderm or secondary cortex is all that tissue produced by the cork cambium on its inner face. Its cells frequently contain chloroplasts.

Histology of a Typical Bark, Cascara Sagrada.—*In transverse section* passing from outer to inner surface, the following structural characteristics are evident:

1. **Cork,** or outer bark, composed of several layers of rectangular cork cells. The most external layers are dead and appear black because they are filled with air. The inner layers of this region are living and contain brownish contents.

2. **Cork Cambium** (phellogen), a layer of delicate cells in the process of division with protoplasmic contents.

3. **Cortex,** or middle bark, consisting of two regions, viz.: an outer zone of two or three rows of brownish collenchyma cells, and an inner broader zone of tangentially elongated cortical parenchyma cells. Imbedded within this zone will be noted numerous groups of stone cells.

4. **Phloem, or inner bark,** a very broad zone composed of irregular-shaped, elongated phloem masses separated from each other by medullary-rays which converge in the outer phloem region. Each phloem mass consists of numerous sieve tubes and phloem cells, some

of which latter contain spheroidal starch grains while others contain monoclinic prisms or rosette aggregates of calcium oxalate. Embedded within the phloem masses, in tier-like fashion, will be noted groups of bast fibers, each group of which is surrounded by a row

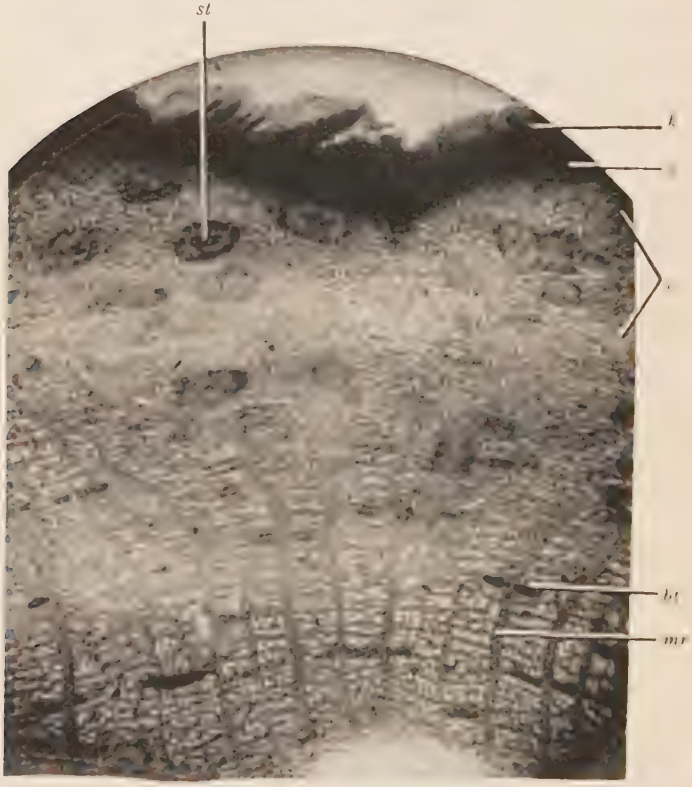

FIG. 109.—Photomicrograph of transverse section of Cascara Sagrada bark; *k*, cork; *c*, cork cambium; *c*, cortex; *st*, group of stone cells; *bf*, group of bast fibers; *mr*, medullary ray.

of crystal fibers, individual cells of which can only be made out in this kind of a section. Each of these contains a monoclinic prism of calcium oxalate. The medullary-rays possess brownish contents which take a red color with an alkaline solution.

In radial longitudinal section, a lengthwise view of the tissues will be seen. The medullary-rays appear 15 to 25 cells in height and

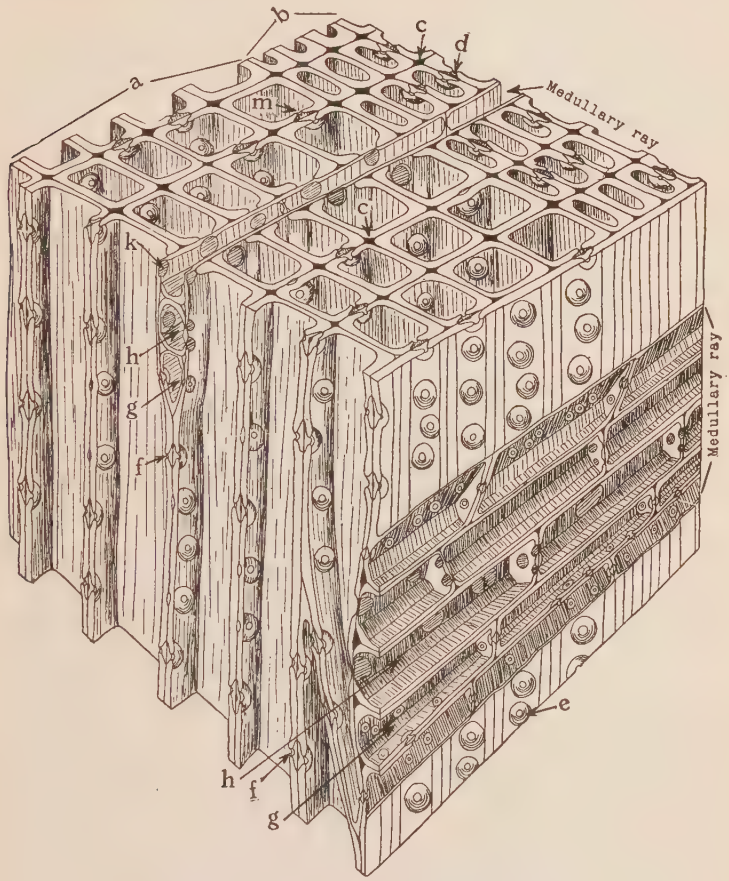

FIG. 110.—Diagrammatic representation of a block of pine wood, highly magnified. *a*, Early growth; *b*, late growth; *c*, intercellular space; *d*, bordered pit in tangential wall of late growth; *m*, *f* and *e*, bordered pit in radial wall of early growth from different points of view; *h*, row of medullary cells for carrying food; *g*, row of medullary ray cells for carrying water; *k*, thin place in radial wall of ray cells that carry food. (*From Stevens.*)

crossing at right angles to the other elements. The crystal fibers here will be seen to be composed of vertical rows of superimposed

thin-walled cells each of which contains a monoclinic prism of calcium oxalate. The bast fibers appear elongated and taper-ended and are associated with crystal fibers.

In a tangential longitudinal section which has been cut through the phloem, the exact range in width of the medullary-rays may be ascertained. In this bark the medullary-rays are spindle-shaped in tangential view and one to four cells in width.

Wood.—From a pharmacognic standpoint as well as that of the lumber trade, wood is all that portion of woody exogenous plant axis inside of the cambium line. In Dicotyl and Gymnosperm stems it therefore includes the xylem regions of the bundles, the xylem portions of the medullary-rays and the pith, while in the roots of secondary growth of these plants it comprises the xylem portions of the bundles and the xylem medullary-rays.

As the cambium year after year adds new layers of wood to that already present on its inner face, the conveying of sap and storing of starch, etc. is gradually relegated to the outer wood layers, since the inner layers, step by step, lose their protoplasmic contents and power of conducting sap and become filled with extractive, resinous and coloring matters. The outer whitish layers of wood which contain living cells, functioning in the vegetative processes of the plant, constitute the **alburnum** or **sap-wood.** The drug Quassia is a good example of this kind of wood. The inner dead colored layers constitute the **duramen** or **heart-wood.** Important examples of this kind of wood used in pharmacy are Lignum Guaiaci, Hæmatoxylon and Santalum Album.

Microscopic Characteristics of Angiospermous and Coniferous Woods.—The wood of Angiosperms is characterized by the presence of tracheæ (vessels) with various markings on their walls, particularly by small pits in the walls of some of the tracheæ, together with wood fibers, wood parenchyma and medullary-rays.

The wood of Conifers is made up for the larger part of tracheids with bordered pits which latter are characterized in radial longitudinal section by the presence of two rings, one within the other. A single row of these is seen on the tracheid wall. Medullary-rays, frequently diagnostic for different species, and wood parenchyma cells are also found.

Histology of Typical Herbaceous Monocotyl Stems (Endogenous). Passing from exterior toward the center the following structures are seen:

1. *Epidermis* whose cells are cutinized in their outer walls.
2. *Hypodermis*, generally collenchymatic.
3. *Cortex*, of parenchyma cells. Sometimes vascular bundles of the closed collateral or the concentric type occur in this region.
4. *Endodermis* or innermost layer of cortex.
5. *Stele* or *Pith*, a large central zone of parenchyma matrix in which are found scattered fibro-vascular bundles of the closed collateral or more rarely of the concentric type. In this latter type,

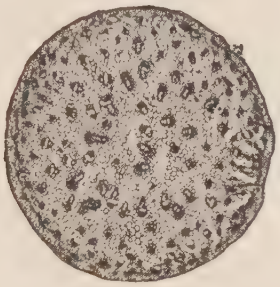

FIG. 111.—Photomicrograph of cross-section of very young cornstalk (a herbaceous monocotyl stem), where certain plerome strands have just gone over into vascular bundles. For comparison with Fig. 112. (*Stevens.*)

which is typical of old monocotyl stems and also seen in Calamus, Convallaria, etc., the xylem grows completely around the phloem so that phloem is found in the center and xylem without and surrounding it.

Histology of a Typical Monocotyl Rhizome.—The rhizome of *Convallaria majalis* (Lily-of-the-Valley) shows typical herbaceous monocotyl rhizome structure. A transverse section (see Fig. 113) presents the following structural details, passing from periphery toward the center:

1. *Epidermis* of a layer of epidermal cells whose outer walls are covered with a waxy cutin deposit.
2. *Hypodermis* of a layer of collenchyma cells.

3. *Cortex* of about 20 rows of ordinary parenchyma cells, some of which contain more or less spheroidal starch grains, others raphides of calcium oxalate.

4. *Endodermis* of usually 2 layers of endodermal cells, the radial and inner walls of which are strongly indurated with lignin.

5. *Stele*, a broad central region consisting of a matrix of starch- and crystal-bearing parenchyma and through which region course closed collateral and concentric bundles.

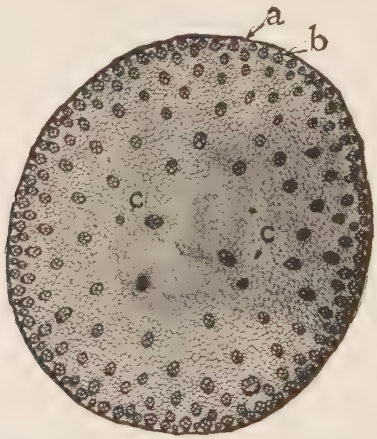

FIG. 112.—Photomicrograph of cross-section of older cornstalk stem; *a*, epidermis; *b*, cortex and *c*, ground tissue. (*After Stevens.*)

The closed collateral bundles are arranged in an interrupted circle just beneath the endodermis. The concentric bundles are scattered through the center of the stele.

Longitudinal-radial sections show that the tracheæ are of the spiral, scalariform and pitted types.

Histology of a Typical Woody Monocotyl Stem.—The stem of the Greenbrier, a woody monocotyl, will here be considered. In transverse section passing from periphery toward the center the following structural details will be noted:

1. *Epidermis*, of a single layer of epidermal cells whose outer walls are strongly cutinized. *Cutin* is a wax-like substance which forms a protective coat to the epidermis, preventing the evaporation of water, the ingress of destructive parasites, and injury from insects.

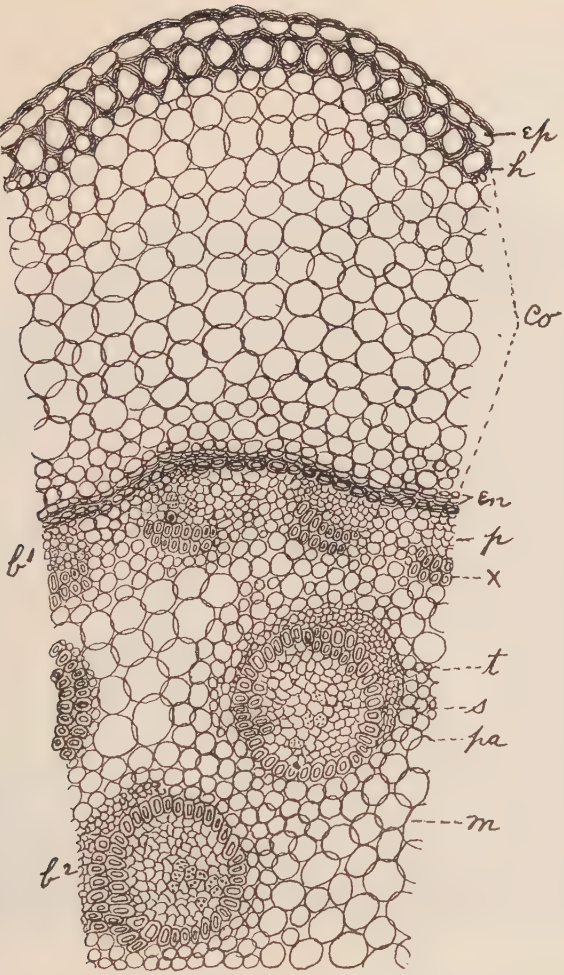

FIG. 113.—Transverse section of a representative portion of Convallaria (Lily-of-the-Valley) rhizome showing herbaceous monocotyl stem structure. Epidermis (*ep*); hypodermis (*h*); cortex (*co*); endodermis (*en*); closed-collateral bundle (b^1); concentric bundle (b^2); phloem (*p*) and xylem (*x*) of a closed bundle; trachea (*t*) and sieve tissues (*s*) of a concentric bundle; parenchyma (*pa*) of stele (*m*).

2. A *cortex*, composed of about ten or twelve layers of thick-walled parenchyma cells, the outer two or three layers of which are termed hypodermis.

3. An *endodermis*, wavy in character and composed of endodermal cells whose brownish walls are strongly suberized.

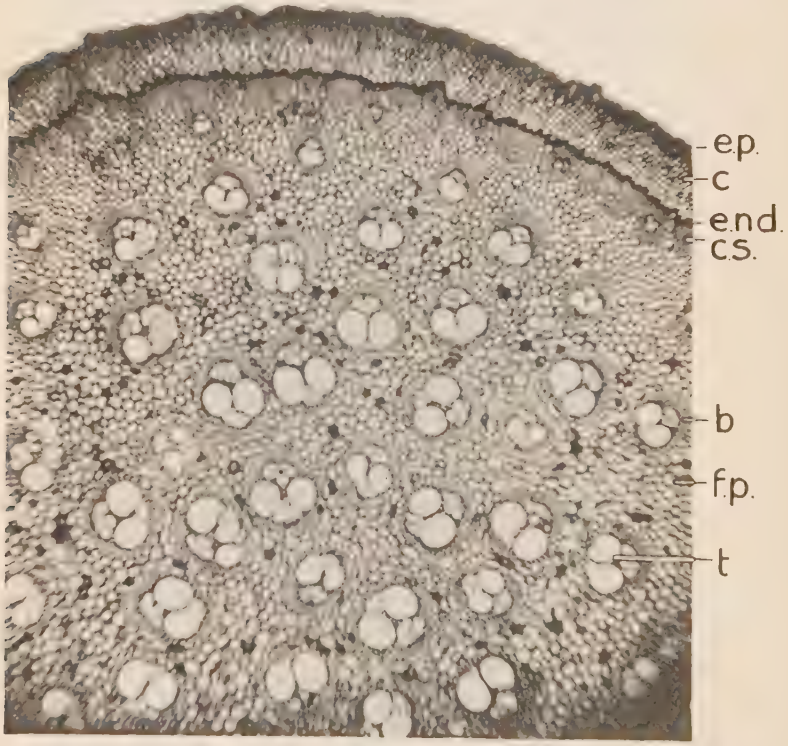

FIG. 114.—Photomicrograph of a representative portion of Greenbrier stem showing epidermis (*e.p.*), cortex (*c*), endodermis (*e.nd.*), cylinder sheath (*c.s.*), sclerenchyma fibers of closed collateral bundle (*b*), fundamental parenchyma (*f.p.*), trachea (*t*). × 22.

4. A sclerenchymatous *cylinder sheath* composed of somewhat separated masses of sclerenchyma fibers and undeveloped fibro-vascular bundles of the closed collateral type.

5. A *central matrix* of strongly thickened parenchyma cells in which are scattered, irregularly, numerous closed collateral bundles. Small starch grains will be found in the parenchyma cells. Examine a representative bundle, and note the two very large tracheæ and several smaller ones in the xylem portion of the bundle which faces toward the center of the section. In the outer or phloem portion of the bundle will be seen an area of soft, small-celled sieve tubes and phloem parenchyma. The entire bundle is enclosed by a several layered ring of sclerenchyma fibers, which on the inner face are called wood fibers, on the outer, bast fibers. The wood fibers constitute the supporting elements of the xylem, while the bast fibers represent the supporting elements of the phloem.

CHAPTER XI

THE LEAF

The leaf is a usually flattened, rarely semi-centric, or centric-lateral expanse developed by the stem or by branches and in whose axil one or more branches arise.

Leaves seldom develop buds over their surface or along their margin and in connection therewith roots. The capacity for bud

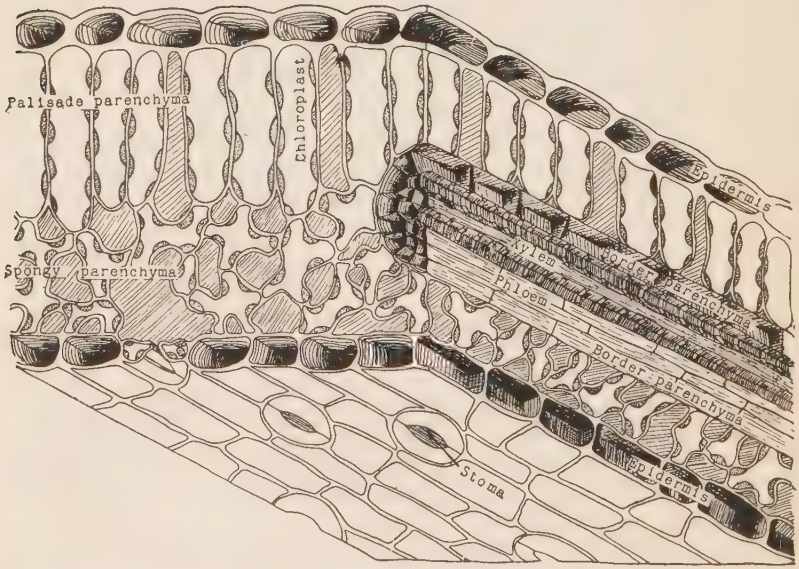

FIG. 115.—Stereogram of leaf structure. Part of a veinlet is shown on the right. Intercellular spaces are shaded. (*From Stevens.*)

development by the leaf is restricted to three families, viz.: *Crassulaceæ*, *Begoniaceæ* and *Gesneraceæ*.

The Complete Leaf.—The leaf when complete consists of three parts, *lamina*, *petiole*, and *stipules*. The **lamina** or **blade** is the

essential part. Other parts may be wanting. It consists of upper and lower surfaces provided with a layer of protective *epidermal cells* which may give rise to outgrowths in the form of hairs or papillæ. Either or both of these surfaces show openings called *stomata* (sing. *stoma*) which are protected by guard cells that regulate their opening and closing. The stomata serve for the exchange of carbon dioxide and oxygen and the escape of water vapor. Between the epidermal layers is a soft green tissue called *mesophyll* which is made up of leaf parenchyma cells containing *chloroplasts* and intercellular-air-spaces. Coursing through the mesophyll are the *veins* or *fibro-vascular bundles* which are in continuity with the fibro-vascular bundles of the stem. These veins branch and rebranch and so make up the frame-work of the lamina. The outer walls of the epidermal cells are provided with a cuticle which is generally thicker on the upper than on the lower surface. In most leaves the mesophyll is differentiated into upper *palisade parenchyma*, lower *spongy-parenchyma* and *border parenchyma* regions and stomata are only found in the lower epidermis.

The **petiole** is the leaf stalk. The **stipules** are leaf-like appendages appearing at the base of the petiole.

The leaf of the Tulip Poplar or Liriodendron affords a good example of a *Complete Leaf*. The stipules of this leaf are in the form of bud scales.

Sometimes the lamina or blade is attached directly to the stem by its base and the leaf is then said to be *sessile*. If the petiole is present, the leaf is *petiolate*.

When leaf stipules are absent, the leaf is said to be *exstipulate* when present, *stipulate*.

The petiole is seldom cylindrical in form, but usually channelled on the upper side, flattened, or compressed. The stipules are always in pairs and closely resemble the leaf in structure.

Leaf Functions.—The most essential function of green plants is the conversion of inorganic into organic matter; this takes place ordinarily in the green parts, containing chlorophyll, and in these when exposed to sunlight. Foliage is an adaptation for increasing the extent of green surface.

The functions of a leaf are *photosynthesis, assimilation, respiration* and *transpiration.*

Photosynthesis is the process possessed by the cells of all green leaves or other green parts of plants of building up sugar, starch or other complex organic (carbon containing) substances by means of chlorophyll and sunlight. This process takes place in nature, only during sunlight. In this process CO_2 is taken in and O given off, carbon compounds are formed and the kinetic energy of the sun's rays becomes stored as potential energy. The plant gains in weight and so the process is constructive in character. In photosynthesis, sunlight is the power, the chloroplasts the working

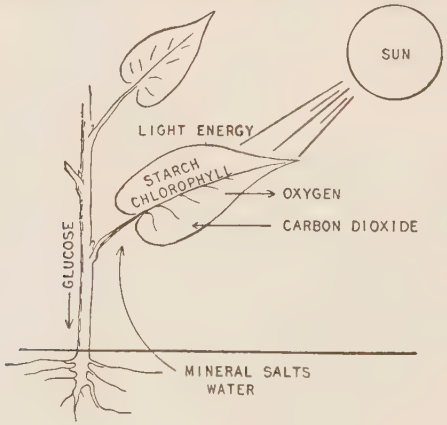

FIG. 116.—Diagram of photosynthesis. (*After Atwood.*)

machinery, CO_2 and H_2O the raw materials and starch or oil the finished products, while oxygen is a waste product.

Assimilation is the process of converting food material into protoplasm.

Respiration is the process which takes place in all living plant and animal cells whereby complex carbon compounds are oxidized with an accompanying release of energy. In higher green plants oxygen is taken in through the stomata of leaves, lenticels of stems, and root hairs. It passes into the intercellular-air-spaces which communicate with each other throughout the entire plant and diffuses through

the various cell-walls of cells, in contact with these, and passes into the interior of the cells. Here it oxidizes some of the carbohydrates breaking these down into carbon dioxide and watery vapor. These diffuse out of the cells into the intercellular-air-spaces and pass out of the plant through the same channels as oxygen entered. Respiration goes on both in light and darkness, organic compounds are broken down, O is absorbed and CO_2 set free, and potential energy is transformed into kinetic energy. The plant loses weight and, accordingly, this process is destructive in character.

Transpiration is the action of giving off watery vapor. The greater portion of the crude sap consisting very largely of water is conveyed upward as a *transpiration stream* through the tracheæ and tracheids of the roots and stems into those of the leaves. The latter pervade the soft, green leaf parenchyma and end in proximity to air spaces between the green cells. A portion of the crude sap diffuses into the leaf parenchyma cells and is utilized in the nutritive processes such as photosynthesis, digestion and assimilation occurring there. The remainder, which normally constitutes the larger part, passes through the intercellular-air-spaces and out of the leaves as watery vapor. About 90 per cent. of the water thus transpired escapes through the stomata, the remainder through the epidermal surface. It has been estimated that a large oak tree transpires about 180 gallons of water per day and that during a growing season of five months it would give off water enough to cover the ground shaded by it to the depth of 20 feet.

Types of Leaves Developed in Angiosperms.—These may be tabulated as follows:

1. Cotyledons (the primitive or seed leaves).
2. Scale leaves.
3. Foliage leaves.
4. Bract leaves; (*a*) primary at base of inflorescence; (*b*) bracteolar leaves (bractèoles) at the base of individual flowers.
5. Sepals.
6. Petals.
7. Microsporophylls (stamens).
8. Megasporophylls (carpels).

Cotyledons.—Cotyledons are the first leaves to appear upon the ascending axis and are single in Monocotyledons, double in Dicotyledons. Occasionally, as in certain Maples, there may be three cotyledons shown. This is due to a splitting of one of the cotyledons. There exist no true cases of polycotyledony (development of many cotyledons) among Angiosperms, as in Gymnosperms. In Monocotyledons the single cotyledon is a terminal structure and truly axial in relation to the hypocotyl and radicle. From a primitively

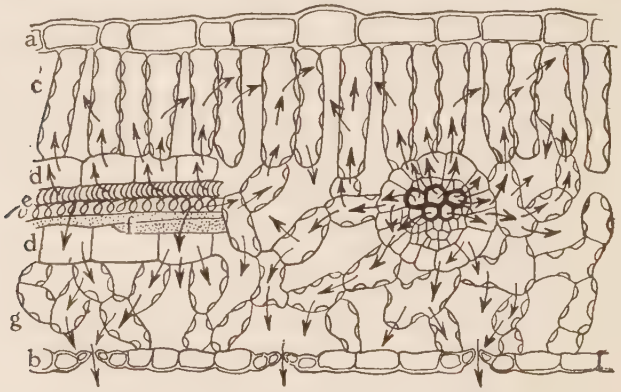

FIG. 117.—Semi-diagrammatic cross section of a dorsoventral leaf of a mesophyte showing by arrows how the water passes from the tracheal elements of a vein into the border parenchyma cells, and thence into the palisade and spongy parenchyma, from which it evaporates into the intercellular spaces and passes from the leaf through the stomata. *a*, upper epidermis; *b*, lower epidermis; *c*, palisade parenchyma; *g*, spongy parenchyma; *d*, border parenchyma; *e*, tracheal elements; and the stippled cells below *e*, the phloem cells. (*After Stevens.*)

Monocotyl-like ancestry Dicotyledons develop a second cotyledon on the epicotyledonary node. Later, by a suppression of the second node the second cotyledon is brought to the level of the first.

Scale Leaves.—Scale leaves are reduced foliage leaves. They are found on certain rhizomes, above ground stems, such as Dodder, Indian Pipe, etc., on bulbs, and forming the protective scales of scaly buds.

Foliage Leaves.—These are the common green leaves so familiar to all.

Bract leaves are modified leaves appearing on inflorescence axes.

Sepals, petals, microsporophylls and **megasporophylls** are floral leaves and will be treated at length under the subject of the flower.

Origin and Development of Leaves.—Leaves arise around the growing apex region of a stem or branch as lateral outgrowths, each consisting at first of a mass of cells called the *primordial leaf*. Through continued cell-division and differentiation of these cells in time the mature leaf is developed. The primordial leaf is formed by a portion of the dermatogen of the growing stem apex, which becomes epidermis, a portion of the periblem, producing mesophyll or leaf parenchyma which grows into this, and a part of the plerome, which becomes vascular tissue within the mesophyll.

In the sub-divisions of cells around the growing stem-apex, the primordial leaves (*primordia*) do not arise exactly at the same time. There is a tendency toward spiral arrangement.

Phyllotaxy.—Phyllotaxy is the study of *leaf arrangement* upon the stem or branch, and this may be either alternate, opposite, whorled, or verticillate, or fascicled. It is a general law in the arrangement of leaves and of all other plant appendages that they are spirally disposed, or on a line which winds around the axis like the thread of a screw. The spiral line is formed by the union of two motions, the circular and the longitudinal, and its most common modification is the circle.

Foliage leaves are usually arranged in separated fashion along the stem, one occurring at each node. This is the form of spiral arrangement called the *alternate* arrangement, as shown by most plants.

The alternate arrangement is said to be two-ranked, when the third leaf is over the first, as in all Grasses; three-ranked, when the fourth is over the first. Example: Sedges. The five-ranked arrangement is the most common, and in this the sixth leaf is directly over the first, two turns being made around the stem to reach it. Examples: Cherry, Apple, Peach, Oak and Willow, etc. As the distance between any two leaves in this arrangement is two-fifths of the circumference of the stem or 144°, the five-ranked arrangement is expressed by the fraction $\frac{2}{5}$. In the eight-ranked arrangement, the ninth leaf stands over the first, and three turns are required to reach

it, hence the fraction $\frac{3}{8}$ expresses it. Of the series of fractions thus obtained, the numerator represents the number of turns to complete a cycle, or to reach the leaf which is directly over the first; the denominator, the number of perpendicular rows on the stem, or the number of leaves, counting along the spiral, from any one to the one directly above it. The one which is chosen as the starting point is marked and taken as o.

Other forms of leaf arrangement are:

Opposite, when a pair of leaves is developed at each node, on opposite sides of the stem. Examples: Mints, Lilac.

Decussate, when the leaves are arranged in pairs successively along the stem, at right angles to each other. Example: Thoroughwort.

Whorled or *Verticillate*, when three or more form a circle about the stem. Examples: Canada Lily and Culver's Root.

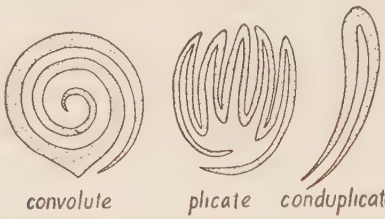

FIG. 118.—Three principal types of vernation. (*Robbins.*)

Fascicled or *Tufted*, when a cluster of leaves is borne from a single node, as in the Larch and Pine.

Vernation.—*Prefoliation* or *Vernation* relates to the way in which leaves are disposed in the bud. A study of the individual leaf enables us to distinguish the following forms. When the apex is bent inward toward the base, as in the leaf of the Tulip Tree, it is said to be *inflexed* or *reclinate vernation;* if doubled on the midrib so that the two halves are brought together, as in the Oak or Peach, it is *conduplicate;* when rolled inward from one margin to the other, as in the Wild Cherry, it is *convolute;* when rolled from apex to base, as in Ferns, it is *circinate;* when folded or plaited, like a fan, as in Ricinus, Maples, Aralias, etc., it is *plicate;* if rolled inward from each margin toward the midrib on the upper side, as the leaves of the Apple or Violet, *involute;* when rolled outward from each margin as

Dock or Willow leaves, *revolute*. The inner surface is always that which will form the upper surface when expanded.

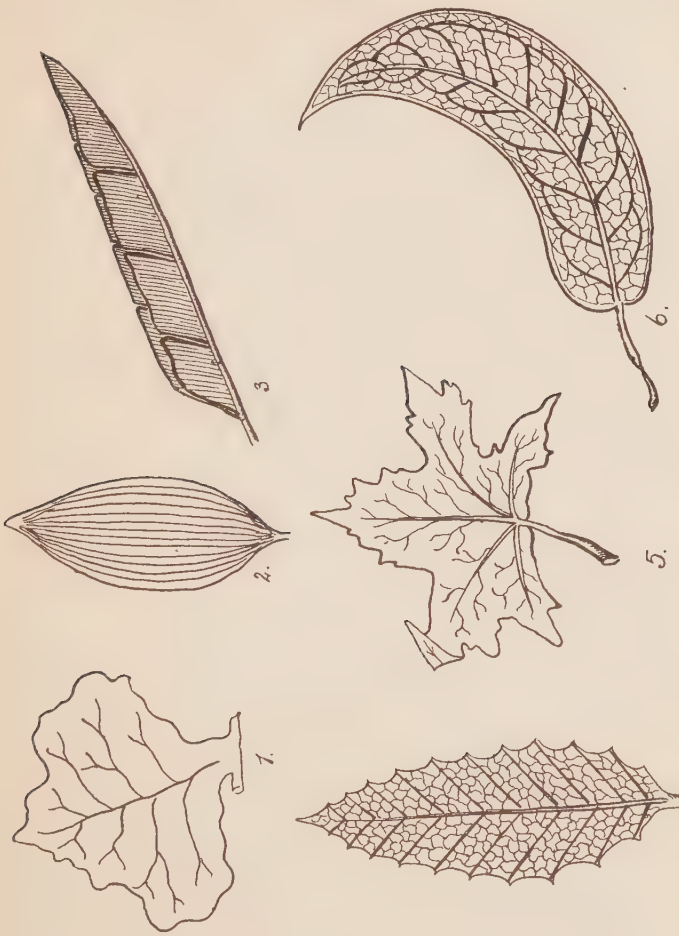

FIG. 119.—Leaf venation. 1. Furcate (Botrychium, a fern). 2. Parallel (Convallaria). 3. Pinnately-parallel (Musa). 4. Pinnate-reticulate (Castanea). 5. Palmate-reticulate (Acer). 6. Pinnate-reticulate with marginal veins anastomosing (Eucalyptus). (*Drawing by Canis.*)

Leaf Venation.—This refers to the arrangement of the veins within the leaf. It is dependent upon the course pursued by the fibrovascular bundles after they enter the leaf blade.

The central vein in the leaf is termed the *midrib* or *primary*. The branches coming off of the midrib are called *secondary veins* or *secondaries;* those arising from secondary veins are called *tertiaries*. Strong and thick veins are called *ribs* and less prominent ones, especially if lateral to the midrib, *nerves*.

Furcate- or **Forked-Venation** is characteristic of leaves of the Ferns.

Parallel Venation is typical of the leaves of *Monocotyledons*, as Palms, Lilies, Grasses, etc. In this type of veining the veins visible to the unaided eye extend in somewhat parallel fashion through the leaf, converging near the summit. In pinnately-parallel veined leaves, as the Banana and Calla Lily, parallel veins extend from midrib to margin.

Reticulate or **Netted Veins** characterize the leaves of *Dicotyledons*, as Matico and the Poplar or Oak. The primary veins in these are generally pinnate or palmate while the secondary ones and their branches are arranged in netted fashion.

Pinnately-veined or **Feathered-veined** leaves consist of a midrib with lateral veins, extending from midrib to margin at frequent intervals and in a regular manner. Examples: Beech and Chestnut leaves.

Palmately Veined leaves consist of a number of veins of nearly the same size, radiating from petiole to margin. Examples: Maple and Castor Oil leaves.

In palmately-veined leaves, the central vein is termed the *midrib* or *middle primary* and those veins lateral to it, the *lateral primaries*.

Most pinnately-veined leaves and palmately-veined leaves show net-veins combined with the basic pinnate or palmate type and so are said to exhibit *pinnate-reticulate* or *palmate-reticulate* venation respectively.

Veins are said to be **anastomosing** when they subdivide and join each other, as the veins near the margin of *Eucalyptus* leaves; **tessellated,** when they form square meshes, as in Matico leaves; and **impressed** when sunken below the surface.

Leaf Insertion.—The point of attachment of the leaf to the stem is called the insertion. A leaf is:

Radical, when inserted upon an underground stem or a root.

Cauline, when upon an aërial stem.

Ramal, when attached directly to a branch.

When the base of a sessile leaf is extended completely around the stem it is *perfoliate*, the stem appearing to pass through the blade. Example: *Uvularia perfoliata* or Mealy Bellwort.

FIG. 120.—Leaf outline: Linear (1); linear-lanceolate (2); lanceolate (3); ovate (4); elliptical (5); orbicular (6); oblanceolate (7); cuneate (8); spatulate (9); falcate (10); ensiform (11). (*Drawing by Canis.*)

When a sessile leaf surrounds the stem more or less at the base, it is called *clasping* or *amplexicaul*. Example: Poppy (*Papaver somniferum*).

When the bases of two opposite leaves are so united as to form one piece, the leaf is called *connate-perfoliate*, as *Eupatorium perfoliatum* or Boneset.

Leaves are called *equitant* when they are all radical and successively folded on each other toward their bases, as in *Iris* sp.

The Forms of Leaves.—**Simple leaves** are those having a single blade, either sessile or petiolate.

Compound leaves are those whose blades are divided into two or more distinct subdivisions called *leaflets*. The leaflets may be either sessile or petiolate. If the compound leaf has leaflets arising from the midrib, it is called **pinnately compound.** The midrib of a compound leaf is sometimes called the *rachis*. If the leaflets of a compound leaf come off of the summit of the petiole, the compound leaf is termed **palmately-** or **digitately-compound.** The leaf stalk of a leaflet is called the *petiolule*.

Forms of Lamina.—The lamina of simple leaves and the leaflets of compound leaves are described as to general outline, apex, base, marginal indentations, surface and texture.

(*a*) **General Outline** (form viewed as a whole without regard to indentations of margin).

Linear, long, narrow, ribbon-like of nearly equal breadth throughout, as Linaria.

Filiform, thread-like, as the Asparagus and one of the Sundews.

Acerose or *acicular*, needle-like, as in the Pines.

Subulate, awl-shaped, as in the Arbor Vitæ.

Ovate, egg-shaped, with its length not more than two or three times its breadth, as Boldo.

Obovate, reversely ovate as some leaves of Short Buchu.

Rhomboidal, angularly-ovate, as the Salt Bush.

Lanceolate, like the linear with the exception that the broadest part is a little below the center. Example: Long Buchu.

Elliptical, somewhat longer than wide, with rounded ends and sides. Example: Leaf of Pear.

Oblong, when longer than broad, margins parallel. Example Matico.

Equilateral, margin of the same length on both sides.

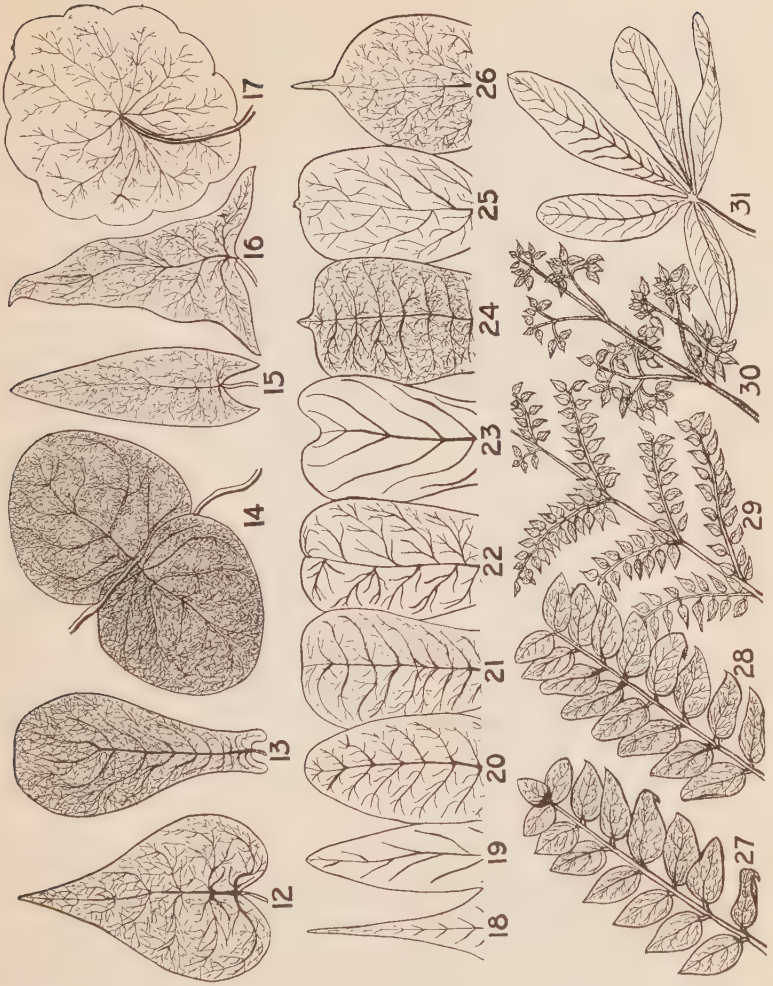

FIG. 121.—Leaf bases (12–17); leaf apices (18–26); compound leaves (27–31). Cordate (12); auriculate (13); connate-perfoliate (14); sagittate (15); hastate (16); peltate (17). Acuminate (18); acute (19); obtuse (20); truncate (21); retuse (22); emarginate (23); cuspidate (24); mucronate (25); aristate (26). Imparipinnate (27); paripinnate (28); bi-pinnate (29); decompound (30); palmately 5-foliate (31).

Inequilateral, margin longer on one side than the other, as the Hamamelis, Elm and Linden.

Orbicular, the blade circular in shape. Example: Nasturtium.

Reniform, or kidney-shaped, as the leaves of Canada Snakeroot.

Oblanceolate, reversely lanceolate. Example: Chimaphila.

Spatulate, like a spatula, with narrow base and broad rounded apex. Example: Some leaves of Uva Ursi.

Ensiform, when shaped like a sword. Example: Calamus.

Falcate, scythe- or sickle-shaped, as leaves on older branches of the Eucalyptus.

Deltoid, when the shape of the Greek letter Δ, as Chenopodium.

(*b*) **Apex of Leaf.**—*Acute*, when the margins form an acute angle at the tip of the leaf giving the tip the appearance of a sharp point. Examples: Eriodictyon, Digitalis.

Acuminate, when the point is longer and more tapering than the acute. Examples: Pellitory, Coffee.

Tapering, if the summit of the leaf be narrowed very gradually to a point, as in leaves of many grasses.

Attenuate, if the summit is still more drawn out than the tapering type.

Obtuse, blunt or rounded. Example: Long Buchu.

Rounded, when extremely obtuse, as in some leaves of Foxglove.

Truncate, abruptly obtuse, as if cut square off. Example: Melilotus leaflets.

Mucronate, terminating in a short, soft point. Example: some Senna leaflets.

Cuspidate, like the last, except that the point is long and rigid.

Aristate, with the apex terminating in a bristle.

Emarginate, notched. Example: Pilocarpus.

Retuse, with a broad, shallow sinus at the apex. Example: Petal of *Rosa gallica*.

Obcordate, inversely heart-shaped. Example: Oxalis.

(*c*) **Base of Leaf.**—*Cordate*, heart-shaped. Examples: Catnep, Violet and Coltsfoot leaves.

Reniform, kidney-shaped. Examples: Ground Ivy, Asarum.

Hastate, or halberd-shaped, when the lobes point outward from the petiole. Example: *Aristolochia Serpentaria*.

Auriculate, having ear-like appendages at the base. Example: Philodendron.

Sagittate, arrow-shaped. Examples: Bindweed and Sagittaria.

Cuneate, wedge-shaped. Examples: Short Buchu and Uva Ursi.

Peltate, or shield-shaped, having the petiole inserted at the center of the lower surface of the lamina. Example: Podophyllum.

Oblique, when the base of the lamina is attached lower on one side of the midrib than the other, as in the Stramonium.

The bases of many leaves extend downward along the stem beyond the main point of insertion when they are called *decurrent*. If the base of the lamina is prolonged downward along the sides of the petiole to which it is joined, the leaf is said to have a *winged petiole*, as in Digitalis.

The terms *acute*, *tapering*, *attenuate*, *truncate*, *obtuse* and *rounded* which have been defined under "Apex of Leaf" are also applied to bases of like character.

(*d*) **Margin of Leaf.**—*Entire*, when the margin is an even line. Example: Belladonna.

Revolute, margin rolled backward.

Involute or *incurved*, margin rolled inward.

Serrate, with sharp teeth which incline forward like the teeth of a hand-saw. Examples: Peppermint, Yerba Santa, Buchu.

Serrulate, when finely saw-toothed, as in Rose leaflets.

Dentate, or *toothed*, with outwardly projecting teeth. Damiana.

Denticulate, when finely toothed.

Crenate, or Scalloped, similar to the preceding forms, but with the teeth much rounded. Examples: Digitalis, Catnip.

Crenulate, when finely scalloped, as in Sage.

In the serrate, dentate and crenate forms, when the teeth show divisions into smaller or secondary teeth, the word "*doubly*" is used as a prefix to the term expressing the character of the primary tooth, thus, *Doubly-serrate*, etc.

Spinose, when the teeth are extended as spines, as in the Holly.

Ciliate, when the margin is fringed with hairs, as in Drosera.

The *sinuses* are the indentations of the margin. If sufficiently deep, they separate the leaf into *segments* or *lobes*.

Repand, or *Undulate*, margin—a wavy line. Example: Hamamelis.

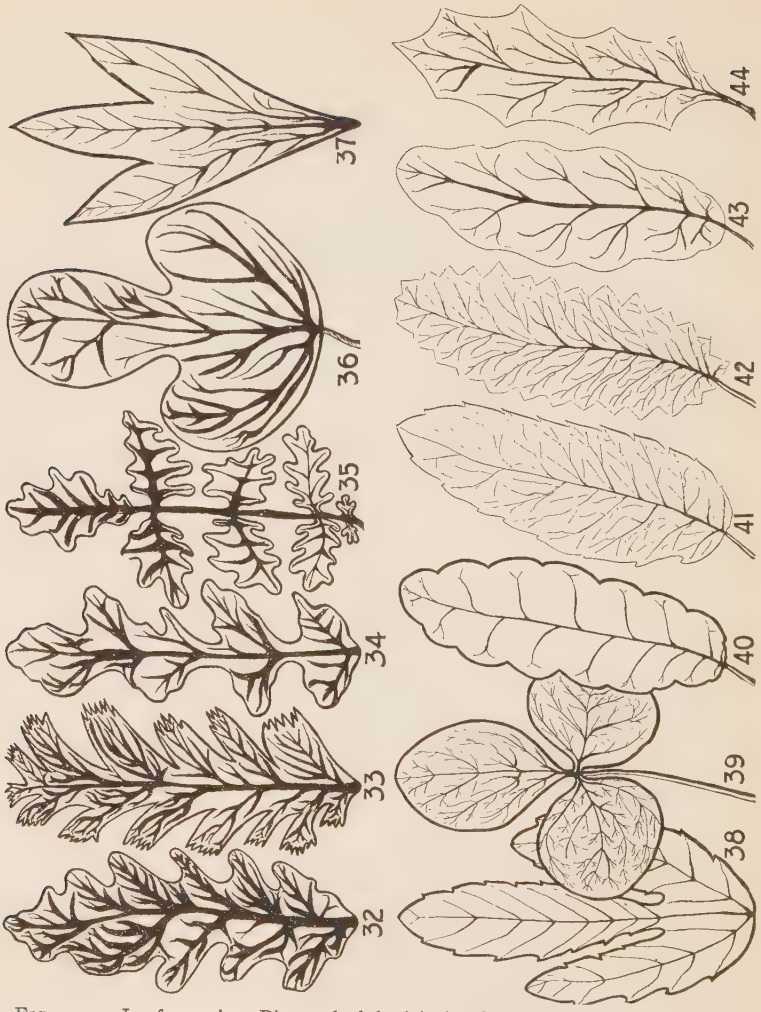

FIG. 122.—Leaf margins: Pinnately-lobed (32); pinnately-cleft (33); pinnately-parted (34); pinnately-divided (35); palmately tri-lobed (36); palmately tri-cleft (37); palmately 3-parted (38); palmately 3-divided (39); crenate (40); serrate (41); dentate (42); repand or undulate (43); sinuate-dentate (44).

Sinuate, when the margin is more distinctly sinuous than the last. (*Stramonium.*)

Incised, cut by sharp, irregular incisions. Example: Hawthorn.

Runcinate, the peculiar form of pinnately-incised leaf observed in the Dandelion and some other *Compositæ* in which the teeth are recurved.

A *Lobed* leaf is one in which the indentations extend toward the mid-rib, or the apex of the petiole, the segments or sinuses, or both, being rounded. Example: Sassafras.

Cleft is the same as lobed, except that the sinuses are deeper, and commonly acute. Example: Dandelion.

A *Parted* leaf is one in which the incisions extend nearly to the mid-rib or the petiole. Example: *Geranium maculatum.*

In the *Divided* leaf the incisions extend to the mid-rib, or the petiole, but the segments are not stalked nor are they in the form of leaflets. Example: Watercress.

If the venation is pinnate, the preceding forms may be described as pinnately-cleft (incised), -lobed, -parted, or -divided. If the venation is (radiate) palmate, then the terms palmately-lobed, -incised, etc., are employed.

Pinnatifid is employed by some authors for describing a pinnately-cleft leaf, *pinnatipartite* for a pinnately-parted one, and *pinnatisect* for one that is pinnately-divided. Likewise *palmatifid*, *palmatipartite* and *palmatisect* are sometimes employed in place of palmately-cleft, palmately-parted and palmately-divided respectively.

A *Pedate* leaf is one which is plamately-parted or divided but which has its lateral lobes in turn divided in more or less linear fashion.

The transition from Simple to Compound Leaves is a very gradual one, so that in many instances it is difficult to determine whether a given form is to be regarded as simple or compound. The number and arrangement of the parts of a compound leaf correspond with the mode of venation, and the same descriptive terms are applied to outline, margin, etc., as in simple leaves.

Leaves are either *pinnately* or *palmately compounded*. The term *pinnate* is frequently given to the former while that of *palmate* is often assigned to the latter. They are said to be abruptly pinnate or *paripinnate* when the leaf is terminated by a pair of leaflets; odd

pinnate or *imparipinnate* when it terminates with a single leaflet. When the leaflets are alternately large and small, the leaf is *inter-*

FIG. 123.—Forms of Leaves. Runcinate leaf of Dandelion (1); lyrate leaf of Turnip (2); interruptedly-pinnate leaf of Potato (3); palmate leaf of Horse-chestnut (4); inequilateral leaf of Witch Hazel (5); pedate leaf of Hellebore (6). Modified leaves of insectivorous plants 7–9. Leaf of a Sundew bearing tentacles (7); leaf of Venus Fly Trap (8); pitchered leaf of Sarracenia purpurea (9); leaf of Heartsease showing free lateral stipules (10).

ruptedly pinnate, as the Potato leaf. When the terminal leaflet is the largest, and the remaining ones diminish in size toward the base the form is known as *lyrate*, illustrated in the leaf of the Turnip.

Palmately compound leaves have the leaflets attached to the apex of the petiole. When these are two in number the leaf is *bifoliate*, or binate; if three in number, *trifoliate*, or ternate, as in Menyanthes; when four in number, *quadrifoliate*, as in four-leafed clover, etc. If each of the leaflets of a palmately compound leaf divides into three, the leaf is called *biternate;* if this form again divides a *triternate* leaf results. Beyond this point the leaf is known as *decompound*. In the case of pinnately-compound leaves, when division progresses so as to separate what would be a leaflet into two or more, the leaf becomes *bipinnate*, as the compound leaves of *Acacia Senegal* or on the new wood of *Gleditschia;* if these become again divided, as in many *Acacia* species, the leaf is termed *tripinnate*. Examples of decompound leaves are seen in Cimicifuga and Parsley.

Leaf Modifications.—The leaves of a number of plants have become modified in one or more parts for the purpose of carrying out special functions coincident with habits acquired by the plants possessing them. Thus, in the common Garden Pea, the upper leaflets are transformed into tendrils for climbing purposes; in the Barberry some of the leaves have become transformed into spines for the defense of the plant from browsing animals; in Squill and Garlic the leaves of the bulbs have become succulent scales for food storage; in the Bladderworts certain submerged leaves have become modified as bladder-like traps for capturing crustaceans; in Sundews, Venus Fly Trap and the Pitcher Plants (*Heliamphora*, *Darlingtonia*, *Sarracenia*, *Nepenthes* and *Cephalotus*) the leaves are variously modified as traps for alluring, capturing and devouring insects.

Leaf Texture.—Leaves are described as:

Membranous, when thin and pliable, as Coca.

Succulent, when thick and fleshy, as Aloes, and Live Forever.

Coriaceous, when thick and leathery, as Eucalyptus, Uva Ursi and Magnolia.

Leaf Color.—*Petaloid*, when of some brilliant color different from the usual green, as the Coleus and Begonia, and other plants which are prized for the beauty of their foliage rather than their blossoms.

Leaf Surface.—Any plant surface is:

Glabrous, when perfectly smooth and free from hairs or protuberances. Example: Tulip.

Glaucous, when covered with bloom, as the Cabbage leaf.

Punctate, when dotted as if by punctures, as in the leaf of the Wax Myrtle.

Pellucid-punctate, when dotted with projections formed by subjacent oil glands, as the leaves of the many members of the Orange family.

Papillose, when covered with minute, teat-shaped projections, as the lower surface of Coca leaves.

Scabrous leaves have a rough surface with minute, elevated, hard points.

Pubescent, covered with short, soft hairs. Example: Strawberry.

Appressed-hairy, when the hairs are curved so as to appear somewhat pressed against the surface, as in Senna leaflets.

Villose, covered with long and shaggy hairs. Example: Forget-me-not.

Sericious, when covered with hairs which give a silky appearance. Example: Silverleaf.

Hispid, when covered with short, stiff hairs. Example: Borage.

Strigose, when covered with appressed, straight, stiff and sharp hairs.

Tomentose, densely pubescent and felt-like, as the Mullein leaf.

Spinose, beset with spines, as in the Thistle.

Rugose, when roughened with closely set wrinkles. Example: Sage.

Verrucose, covered with protuberances or warts, as the calyx of Chenopodium.

Tuberculate, when covered with minute wart-like projections.

Bullate, when blister-like projections appear between the veins.

Duration of Leaves.—Leaves vary as to their period of duration. They are: *Persistent*, or *evergreen*, if they remain green on the tree for a year or more.

Deciduous, if unfolding in spring and falling in autumn.

Caducous, or *fugacious*, if falling early in the season.

Parts of Typical Leaf.—The parts of a typical leaf are *petiole* or leaf stalk, *lamina* or blade, and *stipules*.

THE PETIOLE

The **petiole in Monocotyledons** is usually a broadened, sheathing basal structure which connects the lamina to the stem. In the Grasses and Bananas it forms a long tubular sheath which surrounds the stem. At the point of union of the sheathing petiole and the lamina of a grass is a membranous or leathery ring or flap called the **ligule.** The ligule is not a part of the petiole but is a formation due to the upgrowth and union of a pair of stipules. Into the Grass petiole a set of closed collateral vascular bundles of the stem extend, these showing xylem uppermost and phloem beneath; in the Palms, Aroids, Yams, Bananas, the petiole in part or throughout may be much thickened, strengthened and developed as a semi-cylindric or cylindric structure frequently showing, as in Palms, generally, two sets of bundles. In all of these the petiole shows distinct closed collateral to concentric bundles embedded in parenchyma which in turn is surrounded by epidermis. In the Monocotyl genus *Maranta* of the Arrowroot family, a special swelling is found at the apex of the petiole which is termed a **pulvinus.**

In Dicotyledons, the **petiole** attains its most perfect development and here usually shows differentiation into a short basal part called the **pulvinus** or *leaf cushion* and a longer part, the **stalk** portion.

The pulvinus is sensitive to environal stimuli and in some groups, as *Oxalidaceæ* and *Leguminosæ,* a gradual increase in sensitivity up to a perfect response can be traced. Moreover, in these, if we start with the simpler less sensitive pulvini and pass by stages to the most complex, we note that a special substance known as the *aggregation body* develops in the pulvinar cortex cells and that this substance undergoes rapid molecular change on stimulation of the leaf.

The stalk portion of the petiole in Dicotyledons is usually plano-convex or nearly to quite circular in outline; rarely in certain families does it resemble Monocotyledons in becoming abruptly or gradually thinned or flattened or widened out so as to sheath round the stem. The most striking example of this is seen in the Parsley family (*Umbelliferæ*) where the flattened sheathing leaf stalk is known as

the **pericladium.** Such a structure is not peculiar to the *Umbelliferæ*, for in many members of the Crowfoot family (*Ranunculaceæ*), etc., a similar sheathing development is observed. The stalk may bear the laminar tissue on its extremity. This is most commonly the rule, but when the plant is exposed to xerophytic conditions, as the Acacias of Africa and Australia, the stalk, instead of being cylindric or sub-cylindric, becomes flattened from side to side, until there is produced a bifacial, vertically placed petiole, with a large green surface that wholly takes the place of the lamina. Such a structure is known as a **phyllode** or **phyllodium.**

The **internal structure of the petiole** in primitive types of Dicotyledons resembles that seen in Monocotyledons except that the bundles are more condensed side by side. In these the petiole is somewhat flattened and shows an external epidermis, a flattened cortex and a single row of vascular bundles, each with xylem uppermost and phloem below. From this we can pass to another group of these plants in which the bundles form three-fourths of a circle and in which the upper bundles show incurving orientation, to still another in which, as in *Nepenthes*, all of the bundles form nearly a cylinder. Finally, in *Ficus*, *Geranium*, *Podophyllum* and other plants showing completely formed cylindrical petioles, the bundles form a continuous ring enclosing pith and surrounded by cortex and epidermis, as in Dicotyl stems.

STIPULES

Stipules are lateral leafy or membranous outgrowths from the base of the petiole at its junction with the stem. They may be divided into two groups, viz.: *lateral* and *axillary*. The *lateral group* includes four types, namely, free lateral, lateral adnate, lateral connate and lateral interpetiolar.

Free lateral stipules are seen in *Leguminosæ*, *Rosaceæ*, *Beeches*, etc. They are free on either side of the petiole and supplied by vascular tissue from the petiolar bundle mass. In appearance and duration they may be either green, foliaceous and persistent or membranous to leathery, scale-like and caducous. *Caducous scaly stipules* only function as bud scales, forming a protective covering to the bud through the winter and fall in spring as the buds expand.

Lateral adnate stipules are such as fuse with and are carried up with the petiole as wing-like appendages. This type is seen in the Roses, in Clovers, etc.

Lateral connate stipules are such as join and run up with the petiole to form a structure which is called a **ligule.** This structure is common to the *Gramineæ* or Grass family.

Lateral interpetiolar stipules are common to many species of the *Rubiaceæ.* This family has opposite leaves and in some of the genera, as Cinchona, one stipule from each leaf on either side of the stem unites by its margin with the margin of the other stipule to form an interpetiolar stipule. In this way a stipule is formed on either side of the stem between the opposite leaves.

The **axillary group** represents stipules which stand in the axil of the leaf with the stem. Such may be **free axillary stipules,** arising as distinct processes, or **connate,** when the two stipules unite at their margins, grow up and sheathe the stem, forming a legging-like sheath, as in many species of the *Polygonaceæ* such as Buckwheat, Rhubarb, Yellow Dock, Knot Weeds, etc. The sheath formed is called an **ochrea.**

Modified Stipules.—In some plants such as the Locust and several other trees and shrubs of the Legume family, the stipules become modified for defensive purposes as spines or prickles. In the Sarsaparilla-yielding plants and other species of the genus *Smilax* they undergo modification into tendrils which are useful in climbing.

THE LAMINA

This, as was previously indicated, represents an expansion of the tissues of the petiole, but in sessile leaves is directly attached to the stem and so is a direct stem outgrowth.

Mode of Development of the Lamina of Leaves.—The lamina of leaves develops in one of six ways.

1. Normal or Dorsoventral.
2. Convergent.
3. Centric.
4. Bifacial.
5. Reversed.
6. Ob-dorso-ventral.

The first four will only be considered.

A. **Dorsoventral** (the commonest).

(*a*) *Dorsoventral Umbrophytic.*—Flattened from above downward. Plants with such leaf blades tend to grow in the shade.

(*b*) *Dorsoventral Mesophytic.*—Similar to the former, but plants usually grow directly in the open and exposed to sunlight and winds.

(*c*) *Dorsoventral Xerophytic.*—Similar to former, but plants not only grow exposed, but exposed to hot desert conditions or to cold vigorous conditions.

(*d*) *Dorsoventral Hydrophytic.*—All transitions occur between typical mesophytic forms to those of marshy places, to swamps and borders of streams and finally with leaves wholly emersed, the last a completely hydrophytic type.

Gross Structure and Histology of Different Types of Dorsoventral Leaf Blades.—1. **Dorsoventral Umbrophytic.**—Characterized by leaves mostly undivided and having the largest and most continuous leaf expanse. Usually the deepest green leaves we have, to enable the leaves to absorb scattered and reduced rays that pass in through high trees and shrub overhead. Their texture is usually thin and soft. In microscopic structure they are covered with a cutinized epidermis which has all the stomata on the lower surface. The mesophyll (chlorenchyma) is fairly spongy, the spongy parenchyma having decided intercellular spaces. The lower epidermis is more or less hairy. Examples: Hydrastis, Dog's Tooth Violet, Asters.

2. **Dorsoventral Mesophytic.**—In this type of dorsoventral leaf there is a tendency to subdivision, either to slight or moderate lobing, seldom to complete subdivision in pinnate or tripinnate fashion. Examples: Belladonna, Hyoscyamus, Dandelion, Poplars, etc. In microscopic structure, they consist of an upper and lower epidermis, the upper epidermis being the thicker of the two. The stomata are wholly or are mainly on the lower epidermis. In mesophytic trees and shrubs they are restricted generally to the lower surface while in herbs of mesophytes they may occur on both surfaces although mostly on the lower surface. The palisade parenchyma is toward the upper epidermis and consists of one to three layers of cells. The spongy parenchyma is toward the lower

and consists of irregular, loosely arranged cells with prominent intercellular-air-spaces.

3. **Dorsoventral Xerophytic.**—Leaves characterized by a thick upper and lower cuticle and by having their numerous, small stomata

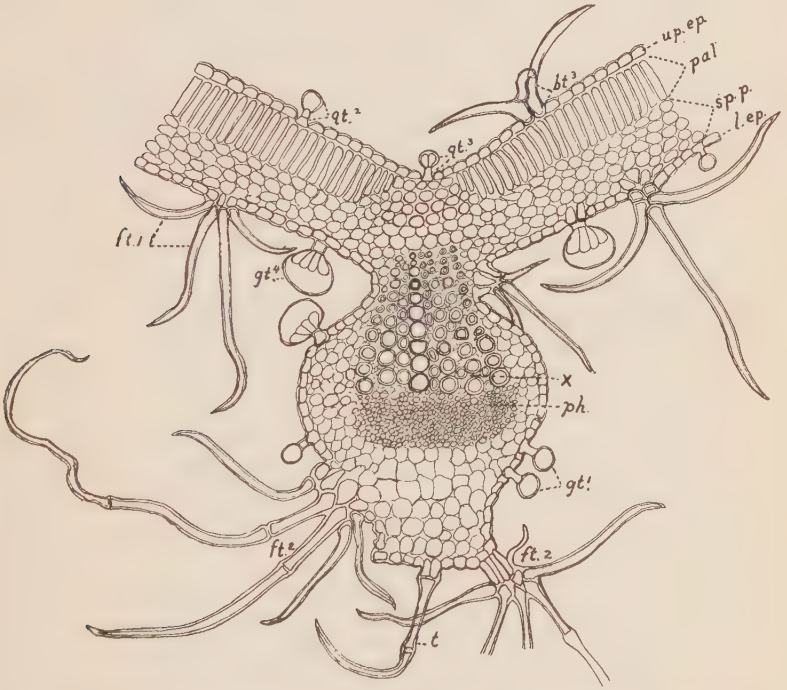

FIG. 124.—Transverse section through portion of dorsoventral leaf blade of horehound (*Marrubium vulgare*). Upper epidermis devoid of stomata (*up.ep.*); lower epidermis which possesses stomata (*l. ep.*); palisade parenchyma (*pal.*); spongy parenchyma (*sp. p.*); xylem (*x*) and phloem (*ph*) regions of fibrovascular tissue of stronger vein; long-pointed non-glandular trichome (*t*); branched trichomes (ft^1, ft^2, ft^3); several types of glandular trichomes (*gt*, gt^2, gt^3, gt^4).

restricted to the lower surface or present more or less equally on both surfaces, where they are sunken in depressions or pits. They may be either firm, leathery, tough, or fibrous, or may become swollen up in their mesophyll, chiefly in their spongy parenchyma cells, and store considerable mucilage. The object of mucilage is

to retain water. Very frequently they develop a water-storage tissue above the mesophyll. Examples: Boldo, Eriodictyon, *Ficus*. Succulent forms like *Aloe* generally possess a thin but tenacious cuticle.

4. **Dorsoventral Hydrophytic.**—All gradations are seen. In pond plants, such as the Water Lily, the leaves have long split petioles which bring the blade up to the surface of the water. The stomata are entirely on the upper surface. In *Ranunculus*, the lower leaves are cut up into filiform segments. These are devoid of stomata. Their mesophyll is soft, open, and spongy. The epidermis is quite thin. The upper leaves are floating, trilobed, and have stomata only on their upper surface. In *Utricularia*, some of the filiform submerged leaves are modified into bladders which trap insect larvæ and smaller Crustaceæ (see Fig. 386).

B. **Convergent.**—In *Phormium tenax*, the base of the blade is sheathing, it then converges and opens out above. In the various species of *Iris* the petiole is sheathing, the upper part being fused (mostly seen in monocotyls).

C. **Centric.**—This type of lamina is semi-centric to centric in shape. It is nearly always associated with Xerophytes. Centric laminæ are produced gradually by an encroachment of the under on the upper surface, and the swelling of the whole. There are two kinds of centric laminæ, the *succulent-centric* and the *xerophytic centric*.

Succulent.—In a completely centric leaf of the succulent kind, like that of Sedum, the difference between the upper and lower surface is lost. Stomata are found scattered over the entire epidermis. The bundles are arranged in a circle, the mid-rib being in the center. A great deal of mucilage is found stored in the central cells.

Xerophytic.—In a typical Xerophytic Centric leaf, like that of the Pine (see Figs. 280 and 125) or *Sanseviera cylindrica*, the epidermis shows a thick cuticle; the stomata are sunken in cavities of the epidermis; the epidermis and leaf tissue are strengthened by scleroid bands in the centric mesophyll.

D. **Bifacial.**—Leaves with laminæ which stand edge on in relation to the sun's rays. The best illustrations are seen among dicotyledons, such as *Eucalyptus*, *Callistemnon*, and other genera of *Myr-*

taceæ. The leaflets of *Cassia Senna* and *Cassia angustifolia* which constitute the drug, Senna, show a marked bifacial structure. Both surfaces are similar, having stomata about equal in number. The mesophyll (chlorenchyma)is differentiated into a central spongy parenchyma containing bundles, and a zone of palisade cells on either side facing the epidermises (see Fig. 126).

Structure and Development of Stomata.—Stomata are slit-like openings in the epidermis of leaves or young green stems surrounded by a pair of cells, called guard cells, whose sides opposite one another are concave. They form a communication between the intercellular-air-space (respiratory cavity) beneath them and the exterior. The

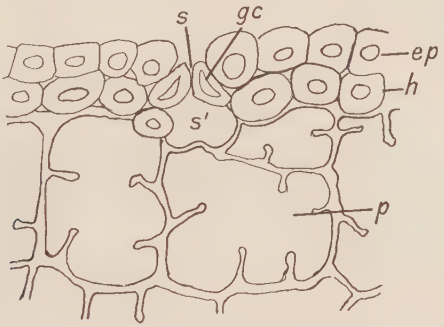

FIG. 125.—Portion of a transverse section of the White Pine leaf showing xerophytic-centric structure. *ep*, Epidermis; *s*, stoma; *gc*, guard cells; *s'*, substomal air-space; *h*, hypodermis, consisting of strengthening fibers which form a scleroid band beneath epidermis; *p*, infolded parenchyma cell of mesophyll. Greatly enlarged.

slit-like opening, taken with the guard cells, constitutes what is known as the *stomatal apparatus*.

The epidermal cells which abut on the stomatal apparatus are called *neighboring cells* or *subsidiary cells*. These, in many cases, as in species of *Helleborus*, *Sambucus*, *Hyacinthus*, *Pæonia*, Ferns, etc., are very similar to the other epidermal cells, but in a large number of plants they differ in size, arrangement and shape from the other cells of the epidermis which do not abut upon the stomatal apparatus. In *Senna* they are mostly two in number, one larger than the other and arranged parallel to the guard cells of the stoma; in *Coca* a

similar arrangement occurs but the cells are more even in size, nevertheless they lack the characteristic papillæ found on the other epidermal cells; in *Pilocarpus* they are usually four in number but quite narrow and more or less crescent-shaped; in *Uva Ursi* their number is usually seven to eight and their arrangement radial around the stomatal apparatus.

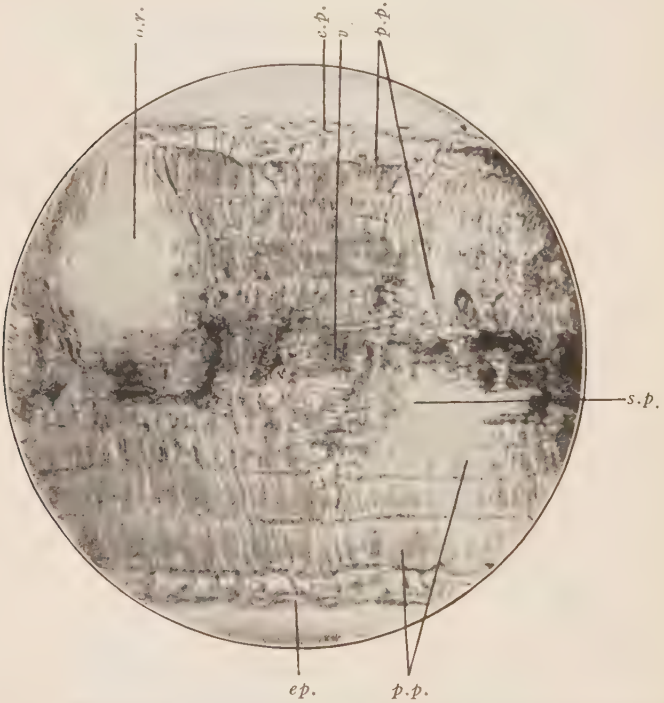

FIG. 126. Photomicrograph of a transverse section of a bifacial leaf of *Eucalyptus globulus* showing epidermis (*ep.*), palisade parenchyma (*p.p.*), toward both surfaces, spongy parenchyma (*s.p.*), vein (*v*), and oil reservoir (*o.r.*) lined with secretory epithelium. (Highly magnified.)

On all dorsoventral leaves, the stomata arise more abundantly on the lower epidermis, less abundantly on the upper. Exceptions to this rule are due to the peculiar readaptation of the leaf to its surroundings. Thus, in the reversed types of leaves (twisted in a half circle) the stomata, formerly on the lower surface, have migrated to

the upper surface which now has become the physiological lower surface.

In Umbrophytic (shade) plants the stomata are either wholly on the lower surface or partly so with a number on the upper surface. Where the plants are Mesophytic and exposed to dense sunlight and leaves remain dorsoventral, the stomata are on the lower surface; these stomata are large, if the surroundings are damp. If such plants live in dry soil and dry air, the stomata are of small size and numerous; if they dwell in dry soil in hot surroundings and dense light they are very small and frequently sunken. If the plants are Xerophytic and the leaves dorsoventral, the stomata are quite abundant, small, with narrow slit, and depressed below the level of the epidermis.

There are five types of stomatal development, viz.:

First Type.—Each primitive epidermal cell (or the majority, or only certain ones of the epidermis) at the close of the dermatogen stage, gradually lengthens and then cuts off a smaller from a larger cell. The smaller one is equilateral, has a very large nucleus, and is termed the *Stoma Mother-cell;* the larger, quadrangular, and called the *Epidermal Daughter-cell.* The latter, upon maturing, becomes a normal epidermal cell. A partition is laid down lengthwise through the *Stoma Mother-cell* dividing it into two stomatal daughter-cells. The wall laid down lengthwise splits and thus forms the orifice of the stoma; the cells on either side of the orifice are called *Guard Cells.* These, while at first flat and inoperative, soon become bulged and crescent-shaped. This mode of development is seen in *Squill, Hyacinth, Daffodil, Sambucus, Silene,* etc.

Second Type.—After the cutting off of the stomal mother-cell, there are cut off, on either side, portions of neighboring epidermal cells which form subsidiary cells to the stoma. This condition is seen in *Gramineæ, Cyperaceæ, Juncaceæ,* in various species of *Aloe, Musa* and *Proteaceæ.*

Third Type.—Instead of two parallel subsidiary cells, four are cut off, as in *Heliconia,* in species of *Tradescantia, Araucaria,* or four to five, as in *Ficus elastica,* or four to five or more, as in the *Coniferæ* and *Cycads.*

Fourth Type.—Instead of only four subsidiary cells, each of these again subdivides by parallel walls, more rarely by radial walls, into eight radiating subsidiary cells, as in *Maranta bicolor, Pothos argyræa,* some of *Proteaceæ,* etc.

Fifth Type.—The "stomal mother-cell" divides once or several times before becoming the true mother-cell of the stoma. As a result of the divisions there are also formed one or more subsidiary

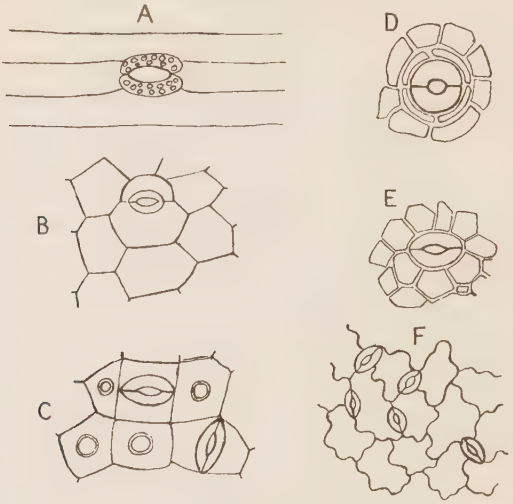

FIG. 127.—Types of stomatal apparatuses and neighboring cells from different sources. In A, a portion of the lower epidermis of Easter Lily leaf. The stomatal apparatus is surrounded by neighboring cells that are similar to other epidermal cells adjacent to them; in B, lower epidermis of Senna leaflet, note the two neighboring cells parallel to the guard cells, one being larger than the other; C, lower epidermis of Coca leaf showing two neighboring cells, parallel to the guard cells but nearly equal in size as well as papillated regular epidermal cells; D, lower epidermis of Pilocarpus showing rounded stomatal apparatus and four crescent-shaped neighboring cells; E, lower epidermis of Uva Ursi, showing eight neighboring cells arranged radiately around stomatal apparatus; F, lower epidermis of Stramonium.

cells. This mode of development is seen in the *Labiatæ, Papilionaceæ, Cruciferæ, Solanaceæ, Crassulaceæ, Cactaceæ,* and *Begoniaceæ,* also in a number of ferns.

Histologic Differences between Leaves of Dicotyledons and Monocotyledons.—The following may be cited as broad comparative histologic differences between Dicotyl and Monocotyl leaves:

Dicotyl Leaves	*Monocotyl Leaves*
1. Epidermal cells usually iso-diametric or sinuous.	1. Epidermal cells usually elongate and equilateral.
2. The stomata are on the whole more numerous but smaller.	2. Stomata larger.
3. Non-glandular and glandular hairs frequent on upper but more frequent on lower surface, or both.	3. Hairs rare in Monocotyls.
4. Leaf glands which excrete varied products are rather abundant.	4. Leaf glands rare and only seen as a rule on the sepals.
5. Water stomata over the upper surface, more rarely over the lower surface, are frequent, especially along margins of leaves.	5. Water stomata absent or very rare. Present in some *Araceæ*.
6. Palisade and spongy parenchyma in dicotyledons are more distinct and palisade parenchyma is denser.	6. Palisade and spongy parenchyma are less distinct and dense.
7. The vascular bundles, in their intrinsic elements, are more indurated but the accessory fibrous sheath is feebly developed.	7. The vascular bundles, in their intrinsic elements, are less indurated. The fibrous sheath is strongly developed.
8. A greater variety of accessory products of assimilation are developed.	8. A comparatively small variety of accessory products of assimilation are developed.

CHAPTER XII

THE INFLORESCENCE

Inflorescence of Anthotaxy.—The terms Inflorescence and Anthotaxy are applied to the arrangement of the flowers and their position on the stem, both of which are governed by the same law which determines the arrangement of leaves.

Indeterminate, racemose, ascending, or *centripetal inflorescence* is that form in which the terminal bud of the flower cluster continues to develop and increase the length of the stem indefinitely. As the stem elongates new flower buds arise behind the terminal bud in the axils of reduced foliage leaves called bracts, so that the oldest bud is at the base of the flower cluster and the youngest one is nearest the apex. Example: *Digitalis.*

Determinate, cymose, descending, or *centrifugal* inflorescence is that form in which the opening of the terminal bud as a flower determines or completes the growth of the stem of the flower cluster. Example: *Ricinus communis.*

Mixed inflorescence is a combination of the other two forms. Example: Horse Chestnut.

The flower stalk is known as the *peduncle.* Its prolongation beyond the point where flowers or branches begin to appear is called the *rachis,* or axis of the inflorescence.

The flower stalk of a single flower of an inflorescence is called a *pedicel.* When borne without such support the flower is *sessile.*

A peduncle rising from the ground is called a *scape,* previously mentioned under the subject of stems.

The modified leaves found on the peduncle or its extension, the rachis, are termed *bracts.* These vary much the same as leaf forms, are described in a similar manner, and may be either green or colored. When collected in a whorl at the base of the peduncle they form an *involucre,* the parts of which are sometimes imbricated

or overlapping, like shingles. This is generally green, but sometimes petaloid, as in the Dogwoods. The modified leaves found on pedicels are called *bracteolar leaves* or bracteoles.

FIG. 128.—Inflorescences. 1, indeterminate; 2, determinate; 3, mixed. (*Drawing by Canis.*)

The *Spathe* is a large bract more or less enveloping the inflorescence and often colored, as in the Calla, or membranous, as in the Daffodil.

Indeterminate Inflorescences.—In the indeterminate or centripetal anthotaxy, the flowers are either produced from base to apex,

those blossoming first which are lowest down on the rachis or the flowers open from margin to center. Indeterminate inflorescences thus fall into two groups, viz., the elongated or ascending group and the flat-topped or centripetal group. The principal forms of indeterminate inflorescence are:

Solitary Indeterminate.—The simplest form of inflorescence in which a single flower springs from the axil of a leaf. A number

FIG. 129.

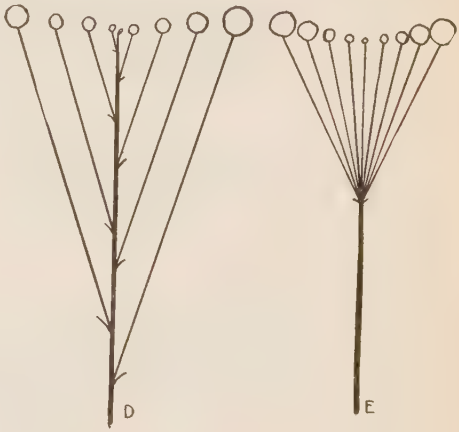

FIG. 130.

FIGS. 129–130.—Types of indeterminate inflorescence. *A*, A raceme; *B*, a spike; *C*, a catkin; *D*, a corymb; *E*, an umbel. The flowers are represented by circles; the age of the flower is indicated by the size. (*From Hamaker.*)

of these are generally developed on the same stem. Example: Periwinkle.

Raceme, or simple flower-cluster in which the flowers, on pedicels of nearly equal length, are arranged along a lengthened rachis, the first flower to open being at the base of the rachis and the last to open at the summit. Examples: Convallaria, Cimicifuga, and Wild Cherry.

Corymb, a short, broad cluster, differing from the raceme mainly in its shorter axis and longer lower pedicels, which give the cluster a flat appearance by bringing the individual florets to nearly the same level. Example: Hawthorn.

Umbel, which resembles the raceme, but has a very short axis, and the nearly equal pedicels radiate from it like the rays of an umbrella.

When the pedicels of an umbel put forth branches, these branches are termed secondary pedicels. Such, then, bear flowers at their tips and make up with other parts of the inflorescence a **compound umbel.** Many examples of this mode of inflorescence are seen in the family *Umbelliferæ*, as indicated by the name, including Anise, Caraway, Fennel and other drug-yielding official plants.

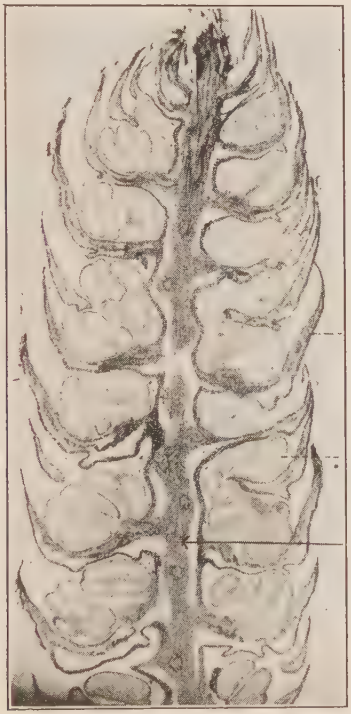

FIG. 131.—Photomicrograph of longitudinal section through a staminate catkin of *Comptonia asplenifolia* × 10, showing catkin axis (*ax*), anther-lobe (*a*), and bract (*b*).

A **Spike** is a cluster of flowers, sessile or nearly so, borne in the axils of bracts on an elongated rachis. The Mullein and common Plantain afford good illustrations. If branches arise from the rachis of a spike and bear flowers, a **compound spike** results. In this type of inflorescence which is seen in Wheat, Rye, Barley and many other

members of the Grass Family, the branch is called the *rachilla* and the secondary inflorescences are termed *spikelets*.

The **Catkin** or **Ament** resembles the *Spike*, but differs in that it is deciduous and usually bears only one kind of flowers, staminate or pistillate, as in the Oak, Hazel, Willow, *Comptonia*, etc.

The **Head** or **Capitulum** is like a spike, except that it has the rachis shortened, so as to form a compact cluster of sessile flowers, as in the Dandelion, Marigold, Clover, and Burdock.

The **Strobile** is a compact spike of unisexual flowers with overlapping scales concealing the flowers, as the inflorescence of the Hop.

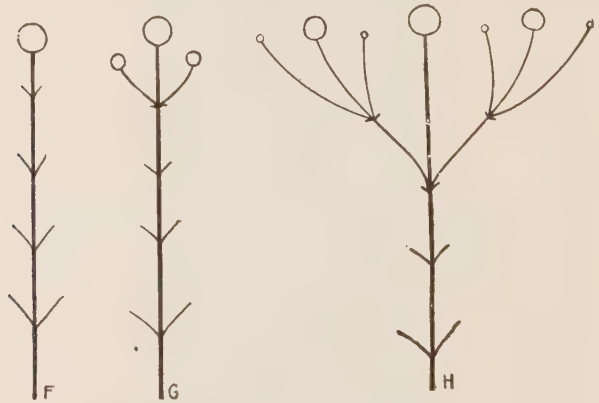

FIG. 132.—Cymose inflorescences. *F*, A terminal flower; *G*, a simple cyme; *H*, a compound cyme. (*From Hamaker.*)

The **Spadix** is a thick, fleshy rachis with flowers closely sessile or embedded on it. It is usually more or less enclosed by a spathe or sheathing bract. Examples: *Calla*, *Calamus*, *Arum triphyllum*.

The raceme, corymb, and umbel, are frequently compounded through the branching of their pedicels. The compound raceme, or raceme with branched pedicels, is called a **panicle.** Examples: Brayera, Yucca and the Oat.

Determinate Inflorescences.—*Determinate Anthotaxy* is one in which the first flower that opens is the terminal one on the axis, the others appearing in succession from apex to base or from center to margin. If the floral axis is elongated, the order of flower develop-

ment is *descending*, or from apex to base; if more or less "flat topped," the order is *centrifugal*, or from center to margin. The principal varieties are:

The **Solitary Determinate,** in which there is a single flower borne on the scape, as in the *Anemone*, or Windflower, the Tulip, and *Hydrastis*.

FIG. 133.—Flowering-branch of a Dogwood showing glomerules. Note the four notched petaloid bracts subtending each glomerule or determinate head of flowers.

The **Cyme,** a flower cluster resembling a corymb, except that the flower buds develop and open from center to circumference. The simplest kind of cyme is seen in the flower cluster of the Linden tree, where a peduncle (arising from a large bract) is elongated into a rachis which ends in a flower bud. At the junction of the rachis with the peduncle, 2 bracteoles arise. In the axil of each of these bracts a bud is formed which elongates in each instance into a pedicel

bearing a flower bud at its end. This type of cyme is called a **simple cyme.** If each of the pedicels give rise to a pair of bracts from the axils of which secondary pedicels arise bearing flowers, a type of *compound cyme* arises called a **dichasial cyme.**

A **Scorpioid Cyme** imitates a raceme, having the flowers pedicelled and arranged along alternate sides of a lengthened axis. These open in right-left fashion from summit to base. Example: Sundew.

A **Glomerule** is a cymose inflorescence of any sort which is condensed into a head, as the so-called head of the Dogwoods (*Cornus*).

A **Verticillaster** is a compact, cymose flower cluster which resembles a whorl, but really consists of two glomerules situated in the axils of opposite leaves. Clusters of this kind are seen in Catnip, Horehound, Peppermint and other plants of the *Labiatæ*.

Mixed Inflorescences are those in which the determinate and indeterminate plans are combined, and illustrations of this are of frequent occurrence.

A **Thyrsus** is a mixed inflorescence more or less pyramidal or oblong in shape consisting of a panicle of cymes, as in the Privet, Lilac, Grape or Horsechestnut. Racemes of cymes and corymbs of cymes are other examples of mixed inflorescences.

CHAPTER XIII

THE FLOWER

The flower is a shoot which has undergone a series of changes so as to serve as a means for the propagation of the individual.

A **Typical or Complete Flower** possesses four whorls of floral leaves arranged upon a more or less shortened and frequently swollen upper end of a stem axis called a **receptacle, torus** or **thalamus.** These whorls passing from periphery toward the center are: **calyx**, composed of parts called sepals; **corolla,** composed of parts termed petals; **androecium,** composed of parts called stamens or microsporophylls; and **gynœcium,** composed of one or more parts termed carpels, pistils, or megasporophylls.

The stem bearing the flower is called the flower stem or **peduncle.**

The stamens and carpels constitute the **essential organs,** and a flower is said to be **Perfect** when these are present and functional. The calyx, corolla and receptacle constitute the **accessory organs** of the flower.

A **Hermaphrodite Flower** is one which possesses both stamens and carpels which may or may not be functionally active. In some cases the stamens may alone be functional while in others the carpels only may function.

A **Regular Flower** possesses parts of each whorl of the same shape and size, as the flower of Veratrum.

A **Symmetrical Flower** is one in which the parts of each whorl are of the same number, or multiples of the same number.

An **Imperfect Flower** shows one set of *essential* organs wanting.

When either petals or sepals, or both, are present in more than the usual number, the flower is said to be "*double*," as the cultivated Rose and Carnation. The doubling of flowers is brought about through cultivation and is due either to the transformation of stamens (as in cases cited), and occasionally of carpels into petals,

to a divison of the petals, or to the formation of a new series of petals.

If the pistils are present and stamens wanting, the flower is called **pistillate,** or female; if it possesses stamens but no pistil, it is described as **staminate,** or male; if both are absent, **neutral,** as marginal flowers of Viburnum. Some plants, as the Begonias and Castor oil, bear both staminate and pistillate, flowers, and are called *Monœcious.* When the staminate and pistillate flowers are borne on different

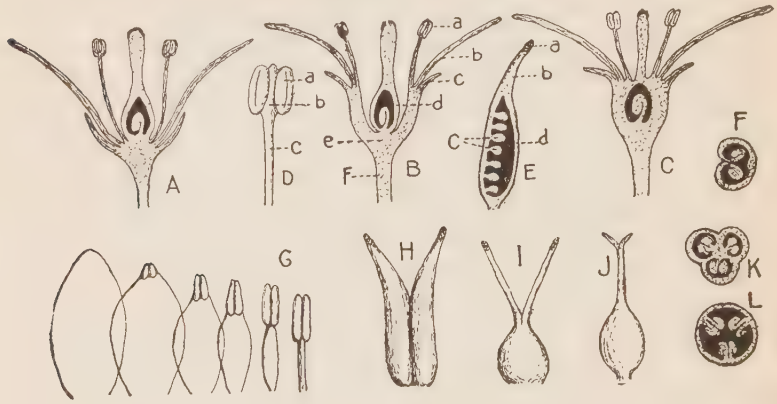

Fig. 134.—Diagrams of floral structures. *A*, Shows the relations of the floral parts in a hypogynous flower; *B*, the same in a perigynous flower; *C*, the same in an epigynous flower; *D*, a stamen; *E*, a simple pistil in longitudinal section; *F*, the same in cross-section; *G*, transitional forms between true petals (left) and true stamens (right); *H*, slight union of two carpels to form a compound pistil; *I* and *J*, union of carpels more complete; *K* and *L*, cross-sections of compound pistils, of three carpels. In *B*: *a*, stamen; *b*, petal; *c*, sepal; *d*, pistil; *e*, receptacle; *f*, pedicel. In *D*: *a*, anther cell; *b*, connective; *c*, filament. In *E*: *a*, stigma; *b*, style; *c*, ovules; *d*, ovary. (*From Hamaker.*)

plants of the same species, they are termed *Diœcious,* as the Sassafras and Willow. When staminate, pistillate and hermaphrodite flowers are all borne on one plant, as on the Maple trees, they are *polygamous.*

Prefloration.—By prefloration is meant the arrangement of the floral envelopes in the bud. It is to the flower bud what vernation is to the leaf bud, the same descriptive terms being largely employed, as convolute, involute, revolute, plicate, imbricate, etc.

In addition to those already defined under *vernation,* the following are important.

Valvate Prefloration, in which the margins of the parts meet but do not overlap. Of this variety the induplicate has its two margins rolled inward, as in Clematis. In the reduplicate, they are turned outward, as the sepals of Althæa.

Vexillary, the variety shown in the corolla of the Pea, where the two lower petals are overlapped by two lateral ones, and the four in turn overlapped by the larger upper ones.

Contorted, where one margin is invariably exterior and the other interior, giving the bud a twisted appearance, as in the Oleander and Phlox.

FIG. 135.

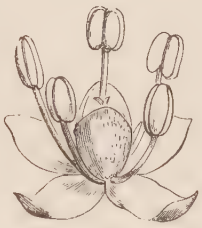

FIG. 136.

FIG. 135.—Flower of the Ash (*Fraxinus*) both calyx and corolla absent (*achlamydeous*).

FIG. 136.—Flower of the Goosefoot (*Chenopodium*) with a calyx but no corolla (*monochlamydeous*). (*After Small.*)

Connation and Adnation.—In the development of the flowers of primitive species of flowering plants, the parts of each whorl are disjoined or separate from each other. In many higher types, however, the parts of the same whorl frequently become partly or completely united laterally. This condition is termed *connation*, *coalescence*, *cohesion* or *syngenesis*. Illustrations of this may be seen in Belladonna, Stramonium, and Uva Ursi flowers, where the petals have joined laterally to form gamopetalous corollas. When the one or more parts of different whorls are united, as of stamens with petals (*Rhamnus*) or stamens with carpels (*Apocynum*), the union is called *adnation* or *adhesion*.

The Receptacle.—The *Receptacle*, *Torus* or *Thalamus* is a more or less shortened axis or reduced branch which bears the floral leaves. It is usually flat or convex, but may be conical and fleshy as in the

Strawberry, concave as in the Rose and Fig or show a disc-like modification, as in the Orange. Like other stems it has nodes and internodes. The internodes of the receptable in many species lengthen and separate various whorls. When the lengthening of the internode occurs between calyx and corolla, as in Lychnis, the structure resulting is called an **anthophore**; if between corolla and androecium, as in Passiflora, a **gonophore**; if between androecium and gynoecium, as in Geum, a **gynophore.** In the flowers of the *Umbelliferæ*, the receptacle elongates between the carpels producing the structure called a **carpophore.**

The Perigone.—The perigone or perianth is the floral envelope consisting of calyx and corolla (when present).

FIG. 137.

FIG. 138.

FIG. 139.

FIG. 137.—Chorisepalous and hypogynous calyx of the Pimpernel (*Anagallis*).
FIG. 138.—Gamosepalous and bilabiate calyx of the Deadnettle (*Lamium*).
FIG. 139.—Urceolate calyx of the Henbane (*Hyoscyamus*). (*After Small.*)

When both whorls, *i.e.*, calyx and corolla, are present the flower is said to be *dichlamydeous;* if only calyx is present, *monochlamydeous.*

The Calyx.—The Calyx is the outer whorl of modified leaves. Its parts are called *Sepals.* These may be distinct or separated from one another when the calyx is called **Chorisepalous, Aposepalous** or **Polysepalous.** If the sepals are more or less united at their margins, the calyx is called **Gamosepalous** or **Synsepalous.**

The sepals are usually green—foliaceous or leaf-like—but may be brilliantly colored, hence the term *petaloid* (like the petals) is applied. Examples of flowers having a petaloid calyx: Tulip, Larkspur, Columbine and Aconite.

In the Daisy Family, etc., the calyx is modified in the form of teeth, bristles, hairs or awns and is then called the **pappus.**

In a *gamosepalous calyx*, when the union of sepals is incomplete, the united portion is called the *tube*, the free portion, the *limb*, the orifice of the tube, the *throat*.

FIG. 140.

FIG. 141.

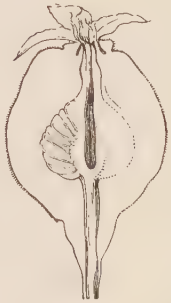

FIG. 142.

FIG. 140.—Campanulate calyx, surrounded by an epicalyx, of the Rose of Sharon (*Hibiscus*).

FIG. 141.—Perigynous and chorisepalous calyx (*cf*) of Rose with concave receptacular tube (*ct*) with stamens (*e*) inserted perigynously on its edge.

FIG. 142.—Peristent epigynous calyx of the Quince (*Cydonia*), showing the receptacular tube completely enveloping the matured carpels. (*After Small.*)

FIG. 143.

FIG. 144.

FIG. 145.

FIG. 143.—Caducous hairy calyx of the Poppy (*Papaver*).

FIG. 144.—Globose persistent calyx of Winter Cherry (*Physalis*).

FIG. 145.—Perigynous chorisepalous calyx of Indian Cress (*Tropæolum*) with spurred receptacular cup. (*After Small.*)

In form the calyx may be regular or irregular; regular, if its parts are evenly developed, and irregular if its parts differ in size and shape. The more common forms are *tubular*, resembling a tube;

rotate, or wheel-shape; *campanulate*, or bell-shaped; *urceolate* or urn-shape; *hypocrateriform*, or salver-shape; *bilabiate*, or two-lipped; corresponding to the different forms of corolla, under which examples illustrating each will be given.

The calyx usually remains after the corolla and stamens have fallen, sometimes even until the fruit matures, as in the Nightshade family; in either case it is said to be *persistent*. If it falls with the

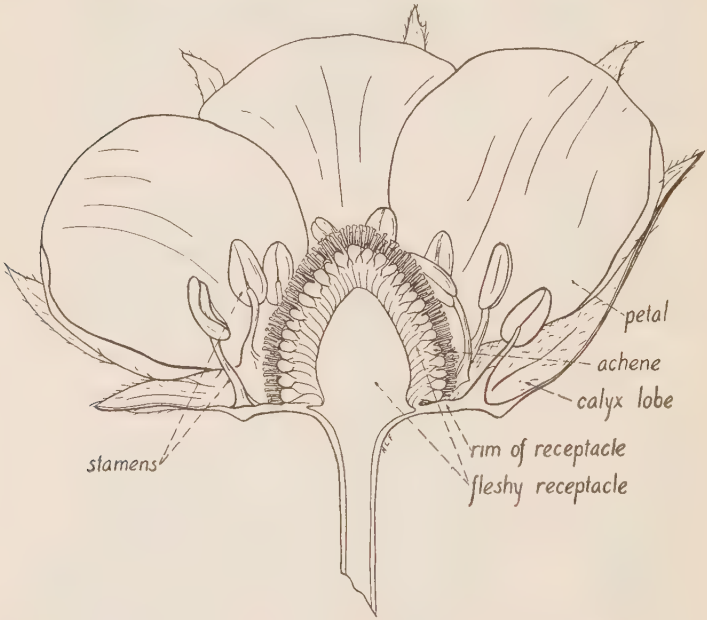

FIG. 146.—Strawberry (*Fragaria chiloensis*). Median lengthwise section of flower. (*After Robbins.*)

corolla and stamens, it is *deciduous*, and if when the flower expands, *caducous*, as in the calyx of Poppy and May-apple. If the calyx falls very early, it is called *fugacious*.

Sepaline Nectaries and Spurs.—Occasionally some or all of the sepals may become pouched and at length spurred as nectar receptacles or as receptacles for other parts that are nectariferous. Thus, in the *Cruciferæ* or Mustard Family, we occasionally see a slight

pouching of the two lateral sepals. These act as nectar pouches for the nectar secreted by nectar glands on the knobs or girdles surrounding the short lateral stamens. These become deep pouches in *Lunaria* while in others the pouches become elongated spurs. Again, in the Larkspurs, the posterior sepal forms an elongated spur into which pass the two spurred nectariferous petals. In *Aconitum* the same sepal, instead of being spurred, forms an enlarged hood-like body called the *galea* or *hood* which arches over the flower like a helmet; into this pass the two hammer-shaped nectariferous petals. In the Wild Columbine (*Aquilegia*) each of the 5 sepals develop a spur.

Sepaline Stipules.—These structures are well developed and easily traceable in the more primitive herbaceous members of the Rose family. Thus in *Potentilla, Fragaria, Geum*, etc., in addition to the normal calyx of five sepals, there is a supplementary whorl of green sepal-like lobes. This is outside of the normal calyx, and is called the **epicalyx.** The five lobes of the epicalyx may be as large or larger than the sepals or smaller up to the disappearing point. Upon examining a few flowers of *Potentilla* or *Fragaria*, it will be observed that not infrequently one, sometimes two lobes of the epicalyx are bifid, or deeply cleft, or separated completely into two parts. The explanation is that the five sepals, after evolving in the flower bud, form at their bases two lateral swellings or *sepaline stipules*, which, as they grow, fuse in adjacent pairs, one stipule of one sepal joining with the adjacent stipule of another sepal to form five lobes.

Sepaline Position.—The most simple and primitive position for the sepals in relation to the floral parts is **hypogynous,** in which the sepals are inserted directly into the enlarged floral axis (receptacle) below the petals, stamens and carpels. But in the more primitive herbaceous *Rosaceæ, Leguminosæ*, etc., the floral axis forms a saucer-like, transverse expansion which pushes out the sepals, petals and stamens on its edge. Thus originates the **perigynous** insertion of the sepals. In not a few higher *Rosaceæ, Saxifragaceæ, Crassulaceæ*, etc., the saucer-like floral axis becomes deepened and contracted into a cup-shaped structure (Cherry, Peach, Almond, Plum, etc.), and on the edge of this cup the sepals as well as the petals and stamens are inserted at different levels. Finally, in the Apple,

Pear, Quince, etc., the greatly hollowed-out receptacle assumes a vase-shaped form and closes over the top of the ovary, at the same time lifting the sepals, petals, and stamens above the ovary. Here the sepals are **epigynous.**

The Corolla.—The Corolla is the inner floral envelope, usually delicate in texture, and showing more or less brilliant colors and

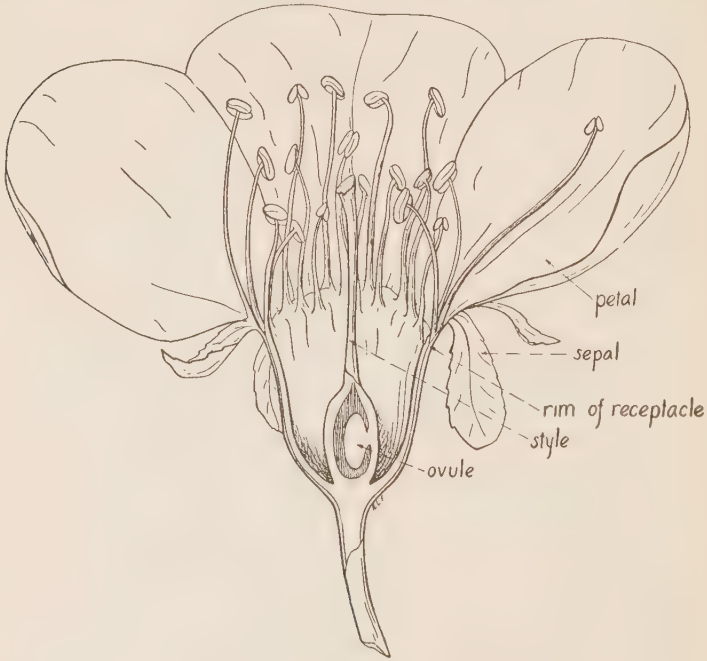

Fig. 147.—Sour Cherry (*Prunus cerasus*). Median longitudinal section of flower. Note the perigynous insertion of the sepals, petals and stamens. (*After Robbins.*)

combinations of color. Its parts are called **Petals,** and when the calyx closely resembles the corolla in structure and coloring they are together called the *Perianth.* The purpose of these envelopes is to protect the reproductive organs within, and also to aid in the fertilization of the flower, as their bright colors, fragrance and saccharine secretions serve to attract pollen-carrying insects.

When the petals are not united with each other, the corolla is said to be **Choripetalous, Apopetalous** or **Polypetalous.** When more or less united into a tubular structure, it is **Gamopetalous,** often called **Synpetalous.**

Forms of the Corolla and Perianth.—When the distinct petals are four in number, and arranged in the form of a cross, the corolla

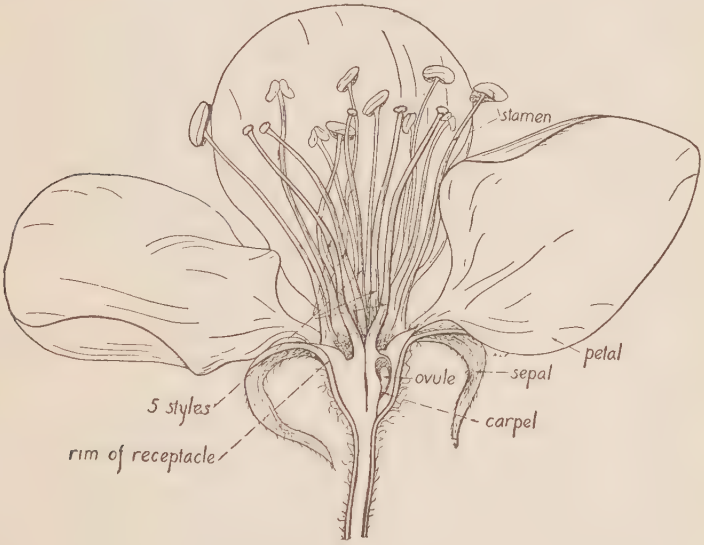

FIG. 148.—Apple (*Malus sylvestris*). Median lengthwise section of flower. Note the epigynous insertion of sepals, petals and stamens. The ovary is inferior. (*After Robbins.*)

is called *Cruciform.* Example: Mustard and other plants belonging to the family Cruciferæ.

The *Papilionaceous corolla* is so called because of a fancied resemblance to a butterfly. The irregularity in this form is very striking, and the petals bear special names: the largest one is the *vexillum*, or standard; the two beneath it the *alæ*, or wings; the two anterior, the *carina* or keel. Examples: Locust, Pea, and Clover.

Orchidaceous flowers are of peculiar irregularity, combining calyx and corolla. The petal in front of stamen and stigma, which differs

from the others in form and secretes nectar, is called the *Labellum*. Examples: *Cypridedium* and other Orchids.

When calyx and corolla each consist of three parts closely resembling each other in form and color, as in the Tulip and Lily, the flower is called *Liliaceous*.

The *Ligulate* or *Strap-shaped corolla* is nearly confined to the family *Compositæ*. It is usually tubular at the base, the remainder resembling a single petal. Examples: Marigold and Arnica Flowers.

Labiate, or *Bilabiate*, having two lips, the upper composed of two petals, the lower one of three. This form of corolla gives the name to the *Labiatæ*, while in the family *Leguminosæ* this arrangement is sometimes reversed. The corolla may be either *ringent*, or gaping, as in Rosemary and Sage, or *personate*, when the throat is nearly closed by a projection of the lower lip, as in Snapdragon and Linaria.

Rotate or *Wheel-shaped*, when the tube is short and the divisions of the limb radiate from it like the spokes of a wheel. Example: The Potato blossom.

Crateriform or *Saucer-shaped*, like the last except that the margin is turned upward or cupped. Example: *Kalmia latifolia* (Mt. Laurel).

Hypocrateriform or *Salver-shaped* (more correctly, hypocraterimorphous), when the tube is long and slender, as in Phlox or Trailing Arbutus and abruptly expands into a flat limb. The name is derived from that of the ancient Salver, or hypocraterium with the stem or handle beneath.

When of nearly cylindrical form, the corolla is *Tubular*, as in the Honeysuckle, and Stramonium.

Funnel-form (Infundibuliform), such as the corolla of the common Morning Glory, a tube gradually enlarging from the base upward into an expanded border or limb.

Campanulate, or *Bell-shaped*, a tube whose length is not more than twice the breadth, and which expands gradually from base to apex. Examples: Canterbury Bell, Harebell.

Urceolate, or *Urn-shaped*, when the tube is globose in shape and the limb at right angles to its axis, as in the official Uva Ursi, Chimaphila and Gaultheria.

FIG. 149.—Illustrating various forms of the corolla. 1, Personate bilabiate corolla of Linaria; 2, cruciform corolla of Rocket; 3, campanulate corolla of Harebell; 4, infundibuliform corolla of Bindweed; 5, ringent bilabiate corolla of Rosemary; 6, spurred calyx of Larkspur; 7, ligulate corolla of Chrysanthemum; 8, rotate corolla of Pimpernel; 9, papilionaceous corolla of Irish Broom; 10, urceolate corolla of Heath.

Caryophyllaceous, when the corolla consists of five petals, each with a long slender claw expanding abruptly at its summit into a broad limb. Examples: Carnation and other members of the Pink family.

Appendages of the Perigone.—In addition to the *spurs* already discussed, the following outgrowths of the perianth may also be encountered:

The **Auricle,** an ear-shaped appendage occurring on the calyx of Lobelia. This term is also applied to similarly shaped lobes of foliage leaves.

The **Awn** is a sharp, rigid outgrowth from the tip or dorsal surface of a perigone lobe.

The **Horn** or **Cornua** is a hollow, horn-like appendage.

The **Cauda** is a long, drawn out, tail-like appendage, as seen in the petals of the Cacao plant.

The **Palate** is a sac-like upgrowth of the lower lip of a personate, bilabiate corolla.

The **Keel** is a ridge resembling the keel of a boat.

The **Corona or Crown** is a circular upgrowth from the throat of the perianth, as seen in Narcissus. It may represent the upgrowth and coalescence of stipules of perianth segments or stamens.

The Androecium or Stamen System.—The *andrœcium* is the single or double whorl of male organs situated within or above the corolla. It is composed of **stamens** or **microsporophylls.**

A complete stamen (Fig. 134*D*) consists of a more or less slender stalk portion called a **filament** and a terminal appendage called the **anther** or **microsorus.** The anther is generally vertically halved by an upgrowth of the filament, called the **connective,** dividing the anther into two lobes.

Number of Stamens.—When few in number, stamens are said to be *definite;* when very numerous, and not readily counted, they are *indefinite.* The following terms are in common use to express their number:

Monandrous, for a *flower* with but one stamen.

Diandrous, with two stamens.

Triandrous, with three.

Tetrandrous, with four.

Pentandrous, having five.

Hexandrous, six.

Polyandrous, an indefinite number.

The most primitive flowers have numerous stamens, but passing from these to those of more evolved families there occurs a gradual reduction from many to ten, as in *Caryophyllaceæ*, *Leguminosæ* and some *Aceraceæ*, these being in two circles. In *Malvaceæ*, *Umbelliferæ* and other Apopetalous families as well as many Synpetalæ, the number five is typical. But in *Scrophulariaceæ*, while five are developed and fertile in *Verbascum*, four with a fifth staminode (sterile stamen) are found in the allied genus *Celsia*. In *Pentstemon* there are four didynamous fertile stamens and an equally long staminode. In *Scrophularia* the fifth staminode is reduced to a petaloid flap in the posterior part of the flower. In *Linaria* this exists only as a small knob at the base of the back part of the corolla and there secretes nectar. In most *Scrophulariaceæ* the fifth stamen is entirely absent and the four stamens left are didynamous; but in *Calceolaria* two of these are rudimentary and thread-like, the other two alone being well-developed and fertile. In *Veronica* three stamens are entirely absorbed and two only are left as fertile representatives.

Insertion of Stamens.—As to insertion the stamens may be:

Hypogynous, when inserted upon the receptacle below the base of the pistil (see Fig. 134*A*).

Perigynous, when inserted on the calyx or corolla above the base of and lateral to the pistil (see Fig. 134*B*).

Epigynous, when inserted above the ovary (see Fig. 134*C*).

Gynandrous, when inserted upon the pistil, as in Orchids and Aristolochia (see Fig. 150 No. 8).

Proportions of the Stamens.—The stamens may be of equal length; unequal, or of different length.

Didynamous, when there are two pairs, one longer than the other. Examples: Snapdragons, Digitalis, Mints. [Fig. 150 (4).]

Tetradynamous, three pairs, two of the same length, the third shorter. Example: Mustard. [Fig. 150 (6).]

Connation of Stamens.—Terms denoting connection between stamens are:

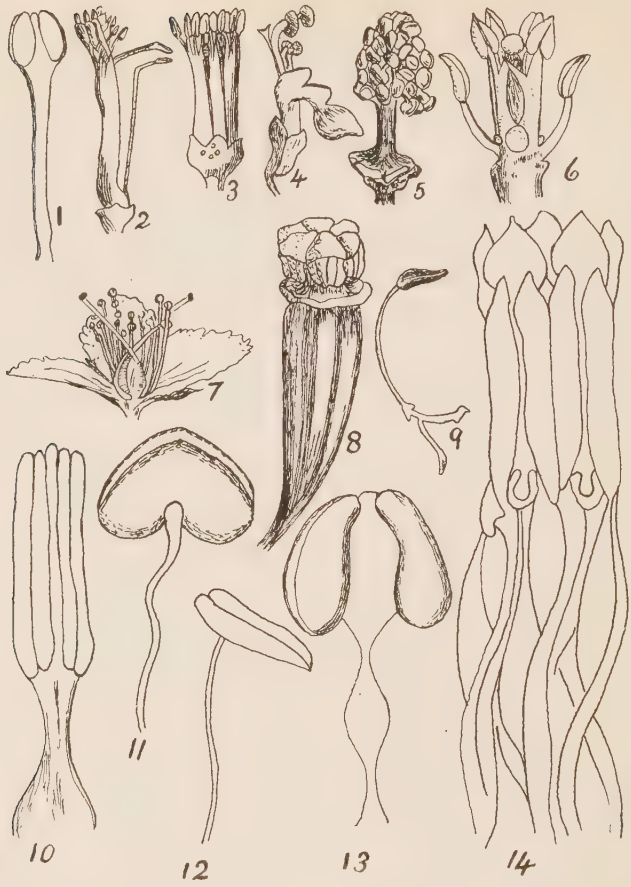

FIG. 150.—The Stamen System. 1, Stamen of *Hepatica* showing adnate anther, the 2 lobes separated by connective; 2, diadelphous stamens of a leguminous plant; 3, polyadelphous stamens of Orange with calyx at base; 4, flower of *Teucrium* showing didynamous stamens; 5, monadelphous stamens of *Malva;* 6, tetradynamous stamens of a Crucifer; 7, flower of *Hypericum* cut vertically to show triadelphous stamens; 8, androecium and gynoecium of *Aristolochia* showing gynandrous stamens; 9, stamen of a Labiate showing branched connective with one anther-sac aborted and absent; 10, adnate anther of *Campanula;* 11, stamen of *Malva* with confluent anther, which is 1-celled; 12, stamen of Lily with versatile anther; 13, stamen of False Rue Anemone with innate anther; 14, stamens of Sunflower showing syngenesious anthers.

Monadelphous (in one brotherhood), coalescence of the filaments into a tube. Examples: *Lobelia* and *Malvaceæ* [Fig. 150 (5).]

Diadelphous (in two brotherhoods), coalescence into two sets. Example: *Glycyrrhiza*. [Fig. 150 (2).]

Triadelphous, with filaments united into three sets. Example: St. John's Wort. [Fig. 150 (7).]

Polyadelphous, when there are several sets or branched bundles. Example: Orange.

Syngenesious, when the anthers cohere. Example: *Compositæ*.

Color of Stamens.—In most species the color of these organs is seldom pronounced owing to their delicate structure. It varies from greenish-yellow to yellow to white, through pink, pinkish-red, red, purple, purple-blue to blue. It is yellow, for instance, in Sassafras, Cucumber and Golden Club; greenish-yellow, yellow to red, in Maples; yellow-pink to pink and pinkish-red, in some Mallows; in *Azalea amena* the filaments are crimson-purple and the anthers, purple-blue; in the genus *Scilla* both filaments and anthers are blue.

Gross Structure and Histology of the Filament.—The filament may be cylindric as in the Rose, awl-shaped as in Tulip, flat and with a dilated base as in the Harebell, three-toothed as in Garlic, appendiculate, when it bears an appendage as in *Chætostoma, Alyssum*, etc. The filament is covered with a protective epidermis containing stomata. Beneath this is a soft, loose, cellular tissue, the mesophyll, and in the center a small vascular bundle, the pathway of food from the floral axis to the anther. In some cases the single bundle may split into two or three bundle parts.

Gross Structure and Histology of the Anther.—Each staminal leaf (**microsporophyll**) bears a special development or appendage, as a rule, on its extremity which is the **anther** or **microsorus.** This consists, fundamentally, of a median prolongation of the filament equal to the connective or placenta. This develops on either side a quantity of indusial tissue that grows out to form a covering substance that protects and carries two **microsporangia** on either side. An *anther*, therefore, consists of a median *connective* or placenta, producing on either side two *anther lobes* or indusial expansions. Each anther lobe encloses two pollen-sacs or *microsporangia*, which, in some cases, remain distinct up to the dehiscence (splitting open)

of the anther. Thus, in *Butomus*, the anthers show four pollen chambers up to the time of dehiscence. Again, in various species of *Lauraceæ*, the anthers remain four lobed and dehisce by four recurved lids. But in the great majority of Angiosperms each pair of pollen sacs fuse before dehiscence, owing to the breaking down of the partition between them, and so, at that time, show two-celled anthers. Still more rarely the anthers may be two-celled in their young state and by the breaking down of the partition become one-celled, *e.g.*, *Malvaceæ*.

Externally the mature anther is bounded by an **exothecium** or epidermis, often swollen, where lines of dehiscence occur, which may develop stomata, also hairs. Within it is a combined layer or set of one to often two or three, sometimes five or six cell layers (*Agave*, etc.) of indusial and sporangial cells, the **endothecium.** The outermost one to three layers of this become spirally, annularly or stellately thickened to form the elastic tissue of the anther, which, by pressure against the delicate epidermis or exothecium, causes ultimate rupture of the anther wall. Within the innermost endothecial layer, bounding each sporangium, is the **tapetum,** a single-celled layer. This, near the time of dehiscence, undergoes breaking down or absorption by developing **pollen** or microspore cells. Filling the cavities of the four sporangia are the mature pollen grains. The connective shows in or near its center a vascular bundle with xylem uppermost and phloem downward, surrounded by thin-walled cellular tissue, from which the indusial and sporangial substance has matured by extension.

Anther Dehiscence.—This is the breaking open of the anther to discharge the pollen.

When fully ripe the dividing partition between each pair of sporangia usually becomes thinned, flattened and ultimately breaks down, while the elastic and resistant endothecium, steadily pushing against the more delicate and now shrinking exothecium causes rupture where endothecium is absent, namely along opposite lines of the anther wall. Thus arises a line of anther dehiscence called *longitudinal anther dehiscence* on either side of the anther sacs. In the division *Solaneæ* of the family *Solanaceæ* which includes Belladonna, in some of the *Ericaceæ* as *Rhododendron* and *Azalea*, etc., the

anthers dehisce by small apical pores from which the pollen is shed. This kind of dehiscence is called *apical porous dehiscence*. Again, in *Lauraceæ* and *Berberidaceæ*, the anthers dehisce by recurved valves (see Fig. 157). This is called *valvular dehiscence*.

Moreover, in *Malvaceæ*, the originally longitudinal anther is divided internally by a partition. It gradually swings on the filament so that eventually the anther is transverse and the partition becomes absorbed, thus becoming a one-celled anther with *transverse dehiscence* in its mature state (see Fig. 150 (11)).

Development of the Anther.—Each stamen originates as a knob-like swelling from the receptacle between the petals and carpels. This swelling represents mainly future soral (anther) tissue. The filament develops later. When such a young sorus or anther is cut

FIG. 151.—Cross-section of a mature lily anther. The pairs of pollen chambers unite to form two pollen sacs, filled with pollen grains; *s*, modified epidermal cells at line of splitting. (*From a Text-book of Botany by Coulter, Barnes, and Cowles. Copyright by the American Book Company, Publishers.*)

across and examined microscopically, it shows a mass of nearly similar cellular tissue in which the first observable changes are the following:

The surface dermatogen cells become somewhat flattened and regular to form the future epidermis or exothecium of the anther. About the same time, some cells, by more rapid division in the middle of the anther substance, give rise to the elements of the

vascular bundle in the connective. Then, along four longitudinal tracts, rows of cells remain undivided or only divided slowly as they increase in size and around them cells divide and redivide to form the future endothecial and covering tissue to the four sporangia. Next, the four sporangial tracts of undivided cells cut off from their outer surfaces a layer of enveloping cells, the *tapetum*. This consists of richly protoplasmic cells that form a covering to the *spore mother-cells* within. Each spore mother-cell undergoes division and redivision into four spore daughter-cells, at the same time that reduction in the chromatin substance takes place in these cells. Thus originate *tetrads* (groups of four) of *spore daughter-cells* inside the spore mother-cell wall. These continue to enlarge, press against the mother-cell wall, which becomes converted into mucilage, and each of the tetrad cells becomes in time a mature *microspore* or *pollen grain*.

During this time the entire anther is growing in size, the cells of the endothecium in one or more layers becomes thickened by lignin deposits to form a *mechanical endothecium;* the *tapetum* gradually breaks down and appears only, at length, as an irregular layer around the maturing pollen cells. When the anther is finally ripe the partition between each pair of microsporangia becomes narrowed, flattened and ruptured and thus numerous microspores or pollen grains fill two cavities, one on either side of the connective. The microspores or pollen grains at first show only a thin, clear, cellulose layer, but from this, by a differentiation of the exterior film, the *exospore* layer becomes cut off. This becomes cuticular. The cellulose inner layer (*endospore*), remains unaltered. In the development of the exospore, one to several deficiencies are usually left in it through which the endospore may protrude later as the rudiment of the pollen tube.

Attachment of Anther.—The attachment of the anther to the filament may be in one of several ways, as follows:

Innate, attached at its base to the apex of the filament.

Adnate, adherent throughout its length.

Versatile, when the anther is attached near its center to the top of the filament, so that it swings freely. The adnate and versatile types are *introrse* when they face inward, *extrorse* when they face outward.

FIG. 152.—Various forms of pollen grains. Pollen from *Typha latifolia* (*A*), *Zea mays* (*B*), *Ambrosia elatior* (*C*), *Lilium philadelphicum* (*D*), *Pinus* (*E*), *Ranunculus bulbosus* (*F*), *Carpinus caroliniana* (*G*), *Althæa rosea* (*H*), *Oenothera biennis* (*I*). All highly magnified. *Drawing by Hogstad.*

Pollen.—The pollen grains or microspores vary in form for different species and varieties and while they are averagely constant for these, nevertheless, many exceptions have been recorded. The following are some of the commoner forms:

Four Spore Daughter-cells, hanging together, as in the Cat Tail (*Typha*), forming a pollen grain.

Elongated, simple pollen grains, as in *Zostera*.

Dumb-bell shaped, as the pollen of the Pines.

Triangular, as in the Evening Primrose (*Œnothera*) and Clove.

Echinate, as in the *Malvaceæ*.

Fig. 153.

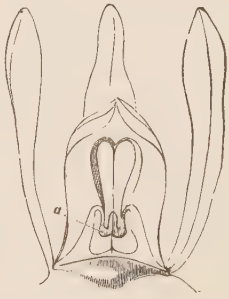

Fig. 154.

Fig. 153.—Orchid Pollinia (*p*), composed of masses of pollen grains, with *caudicle* (*c*), and disc or *retinaculum* (*r*). (*After Small.*)

Fig. 154.—Upper part of Orchid flower, showing the retinacula (*a*) in place within the *rostellum* or sterile stigma. (*After Small.*)

Spherical, as in *Geranium*, Cinnamon and Sassafras.

Lens-shaped, as in the Lily.

Spinose, as in the *Compositæ*.

Barrel-shaped, as in *Polygala*.

Under the microscope, the immature pollen grain generally consists of two membranes, an outer firmer one called the *exospore*, which may be variously marked and which possesses deficiencies in the form of "pores" or "clefts," and an inner delicate cellulose membrane called the *endospore*, which surrounds a protoplasmic interior in which are imbedded a nucleus, oil droplets and frequently starch or protein.

Pollinia.—These are agglutinated pollen masses which are common to the *Orchidaceæ* and *Asclepiadaceæ*.

Hay Fever Pollens.—The pollen of many plants, notably certain species of *Compositæ*, *Chenopodiaceæ*, *Gramineæ*, *Amaranthaceæ*, *Fagaceæ*, *Ulmaceæ*, *Salicaceæ* and *Juglandaceæ*, has been shown to be responsible for "Rose Cold" and "Hay Fever." The chief hay-fever pollens are those of the Ragweeds (*Ambrosia* sp.), Pigweeds (*Amaranthus* sp.), Docks (*Rumex*), Wormwoods (*Artemisia*), Russian Thistle (*Salsola*), various grasses and cereals including timothy, corn, wheat, oats and Buffalo grass, and a number of trees including the oaks, elms, poplars, black walnut, and red cedar. From the investigations of Walker and others, it appears that the symptoms of "Rose Cold" and "Hay Fever" which are seasonable forms of bronchial asthma are induced by the sensitivity of individuals to the proteins of certain pollens. At the present time pollen extracts are manufactured from various pollens to be used in the treatment of this disease.

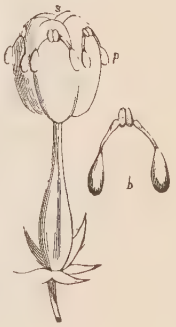

FIG. 155.—Pollinia of a Milkweed (*Asclepias*). *b.* Free. *p.* Adhering to the head of the style, *s.* (*After Small.*)

The Gynœcium or Pistil System.—This is the female system of organs of flowering plants. It may consist of one or more modified leaves called carpels. Each *carpel* or *megasporophyll* is a female organ of reproduction. In the Spruce, Pine, etc., it consists of an open leaf or scale which bears but does not enclose the *ovules*. In angiosperms it forms a closed sac which envelops and protects the *ovules*, and when complete is composed of three parts, the ovary or hollow portion at the base enclosing the *ovules* or rudimentary seeds, the *stigma* or apical portion which receives the pollen grains, and the *style*, or connective which unites these two. The last is nonessential and when wanting the stigma is called sessile, as in the Poppy. The carpel clearly shows its relations to the leaf, though greatly changed in form. The lower portion of a leaf, when folded lengthwise with the margins incurved, represents the *ovary;* the infolded surface upon which the ovules are borne is the *placenta;* a prolongation of the tip of the leaf, the *stigma*, and the narrow intermediate portion, the *style*. *A leaf thus transformed into an ovule-bearing*

organ is called a carpel or *pistil.* The pistils of the Columbine and Pea are made up of single carpels. In the latter the young peas occupy a double row along one of the *sutures* (seams) of the pod. This portion corresponds to the infolded edge of the leaf, and the pod splits open along this line, called the *ventral suture.*

FIG. 156.

FIG. 157.

FIG. 158.

FIG. 159.

FIG. 160.

FORMS OF GYNŒCIUM

FIG. 156.—Monocarpellary pistil of Broom (*Scoparius*). *o*, ovary; *s*, style; *t*, stigma. FIG. 157.—Barberry (*Berberis*). *o*, one-celled or *unilocular* ovary; *ov*, ovules attached to marginal placenta (*p*); *st*, sessile stigma. One stamen dehiscing by recurved valves is shown. FIG. 158.—Bicarpellary, syncarpous gynœcium of Tobacco (*Nicotiana Tabacum*). *o*, ovary; *s*, style; *g*, capitate stigma. FIG. 159.—Syncarpous gynœcium of Primrose (*Primula*) with simple style and capitate stigma. FIG. 160.—Median lengthwise section through flower of Pæony (*Pæonia*). *ds*, dorsal suture of carpel; *vs*, ventral suture. (*After Small.*)

Dehiscence, or the natural opening of the carpel to let free the contained seeds, takes place also along the line which corresponds to the mid-rib of the leaf, the *dorsal suture.*

The gynœcium may consist of a number of separate carpels, as in the buttercup or Water Lily flowers, when it is said to be *apo-*

FIG. 161.

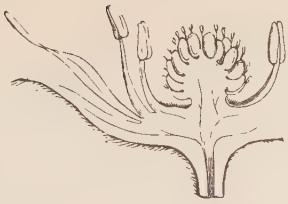

FIG. 162.

FIG. 163.

FIG. 164.

FIG. 165.

FIG. 166.

FIG. 167.

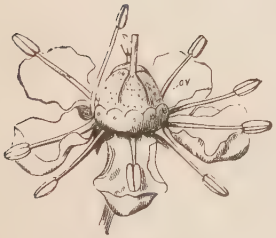

FIG. 168.

FIG. 169.

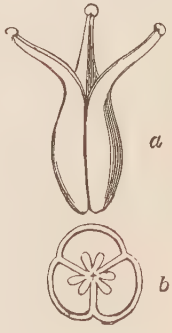

FIG. 170.

FORMS OF GYNŒCIUM

FIG. 161.—Cone of apocarpous carpels (*c*) of Tulip-tree (*Liriodendron tulipifera*). *a*, receptacle; *e*, stamens. FIG. 162.—Apocarpous carpels of Strawberry, raised upon a swollen, hemispherical carpophore. FIG. 163.—Ripened apocarpous carpels of Raspberry on conical receptacle (*l*). FIG. 164.—Apocarpous carpels of Pheasant's Eye (*Adonis*). FIG. 165.—*Zanthoxylum* with gynophore (*g*) and apocarpous ovary (*o*) free styles but united stigmas (*s*). FIG. 166.—Two bi-lobed carpels and gynobasic style (*s*) of Horehound (*Marrubium vulgare*). FIG. 167.—Similar but more distinctly divided gynœcium of Forget-me-not (*Myosotis*). FIG. 168.—Flowers of Rue (*Ruta gravcolens*) to show carpels (*ov*) united only at base. FIG. 169.—*a*, Diagram of three apocarpous carpels; *b*, cross-section of the ovaries of the same. FIG. 170.—*a*, Diagram of three carpels with free styles and united ovaries; *b*, cross-section of the ovaries of the same. (*After Small.*)

carpous, or the carpels composing it may be united together to form a single structure, as in the flowers of Belladonna and Orange, when it is called *syncarpous*.

If the pistil is composed of one carpel, it is called *monocarpellary;* if two carpels enter into its formation, it is said to be *bicarpellary;* if three, *tricarpellary;* if many, *polycarpellary*.

Compound Pistils are composed of carpels which have united to form them, and therefore their ovaries will usually have just as many cells (*locules*) as carpels. When each simple ovary has its placenta, or seed-bearing tissue, at the inner angle, the resulting compound ovary has as many axile or central placentæ as there are carpels, but all more or less consolidated into one. The partitions are called *dissepiments* and form parts of the walls of the ovary. If, however, the carpels are joined by their edges, like the petals of a gamopetalous corolla, there will be but one cell, and the placenta will be parietal, or on the wall of the compound ovary.

Ovules.—The **ovules** or **megasori** are transformed buds, destined to become seeds in the mature fruit. Their number varies from one to hundreds. In position, they are *erect*, growing upward from the base of the ovary, as in the Compositæ; *ascending*, turning upward from the side of the ovary or cell; *pendulous*, like the last except that they turn downward; *horizontal*, when directed straight outward; *suspended*, hanging perpendicularly from the top of the ovary.

In Gymnosperms the ovules are naked; in Angiosperms they are enclosed in a seed vessel.

A complete angiospermous seed ovule which has not undergone maturation consists of a **nucellus** or body; two coats, the outer and inner **integuments;** and a **funiculus,** or stalk. Within the nucellus is found the **embryo sac** or **megaspore** containing protoplasm and a nucleus. (See Fig. 174.)

The coats do not completely envelop the nucleus, but an opening at the apex, called the **foramen** or **micropyle** admits the pollen tube. The vascular plexus near the point where the coats are attached to each other and to the nucellus is called the **chalaza.** The **hilum** marks the point where the funiculus is joined to the ovule, and if

attached to the ovule through a part of its length, the adherent portion of the funuculus is called the **raphe.**

Forms of Ovules.—The shape of the ovule may be **orthotropous,** or straight; **campylotropous,** bent or curved; **amphitropous,** partly inverted; and **anatropous,** inverted. The last two forms are most common. A campylotropous ovule is one whose body is bent so that the hilum and micropyle are approximated.

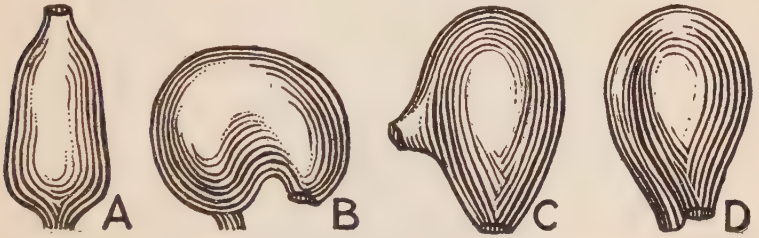

FIG. 171.—Forms of Ovules. *A*, orthotropous. *B*, campylotropous. *C*, amphitropous. *D*, anatropous. (*From Gager, redrawn from Gray.*)

The Placenta.—The placenta is the nutritive tissue connecting the ovules with the wall of the ovary. The various types of placenta arrangement (placentation) are grouped according to their relative complexity as follows: (1) Basilar, (2) Sutural, (3) Parietal, (4) Central, (5) Free Central.

Basilar placentation is well illustrated in the *Polygonaceæ* (Smart Weed, Rhubarb, etc.), in *Piper* and *Juglans.* Here, at the apex of the axis and in the center of the ovarian base, arises a single ovule from a small area of placental tissue.

Sutural placentation is seen in the *Leguminosæ* (Pea, Bean, etc.). Here each carpel has prolonged along its fused edges two cord-like placental twigs, from which start the funiculi or ovule stalks.

Parietal placentation is seen in *Gloxinia, Gesneria, Papaver,* etc. Here we find two or more carpels joined and placental tissue running up along edges of the fused carpels bearing the ovules.

Central or axile placentation is seen in *Campanulaceæ* (Lobelia, etc.), *Solanaceæ,* etc., where the two, three, or more carpels have folded inward until they meet in the center and in the process have carried the originally parietal placenta with them. This then may form a central swelling bearing the ovules over the surface.

Free Central placentation occurs perfectly in the *Primulaceæ*, *Plantaginaceæ* and a few other families. In this the carpels simply cover over or roof in a central placental pillar around which the ovules are scattered.

Style. —The style is the portion of the carpel which connects the stigma with the ovary. It is usually thread-like but may also be considerably thickened. It frequently divides into branches in its upper part. These are called **style arms.** As many style arms as carpels may be present. In the one-carpelled pistil of some *Leguminosæ*, the usually bent-up style is the tapered prolongation of a single flower. Again, in the apocarpous carpels of many flowers of the *Ranunculaceæ*, each carpel bears a short to long stylar prolongation. When the carpels, however, are syncarpous the common styles tend to become more or less fused but usually show lobes, clefts or style arms at their extremities that indicate the number of carpels in each case which form the gynœcium.

In some plants remarkable variations from the typical stylar development may occur. Thus, in *Viola*, the end of the style is a swollen knob on the under surface of which is a concave stigma with a flap or peg. In the genus *Canna*, the style is an elongate, blade-like, flattened body with a sub-terminal stigma. In forms of the *Campanulaceæ*, the style is closely covered with so-called collecting hairs. On these the anthers deposit their pollen at an early period before the flowers have opened. Later, when the flowers open, insects remove the pollen after which the collecting hairs wither. The stigmas then curl apart to expose their viscid stigmatic hairs. In this instance there are two distinct and at separate times functioning hairs on the stylar prolongation, viz.: (*a*) *collecting stylar hairs*, functioning for pollen collection and distribution; and (*b*) *stigmatic hairs* for pollen reception from another flower. In *Vinca*, the style swells near its extremity into a broad circular stigma and then is prolonged into a short *column* bearing a tuft of hairs that prevents the entrance of insect thieves into the flower. In the genus *Iris*, the common style breaks up at the insertion of the perianth into three, wide, petaloid, style arms. Each of these bifurcates at its extremity. On the lower or outer face of this is a transverse flap that bears the stigmatic papillæ. In *Physostigma*, the style

enlarges at its extremity into a flap-like swelling which bears a narrow stigmatic surface. Finally, in *Sarracenia*, the single style of the five-carpelled pistil enlarges above into a huge umbrella-like portion with five radiating ribs. At the extremity of each bifid end of each rib is a minute, peg-like, stigmatic surface.

The Stigma.—This is usually a viscid papillose surface of greater or less expanse functioning for pollen reception. If no style intervenes between the ovary and stigma, the stigma is said to be **sessile.**

FIG. 172.—*Lilium Martagon.* Longitudinal section of the stigma and upper part of the style. The pollen grains, caught on the papillæ of the stigma, have germinated, and the pollen-tubes are growing down along the walls of the style canal. (*From Gager after Dodel-Port.*)

In wind-pollinated flowers such as the grasses, the stigmas are the numerous feathery hairs which cover the ends of the styles and are intended to catch flying pollen grains. Such stigmas are called *plumose.* In animal-pollinated flowers, the stigmas are usually small restricted knobs, lines or depressions. The *stigmatic papillæ* vary in size in different plants and even may vary on different individuals of the same species. Thus, in the long styles of *Primula*, the stigmatic papillæ are elongated, columnar, hair-like

structures, whereas in the short styles of short-styled flowers the papillæ are small knob-like cellular swellings.

Various terms are ascribed to stigmas to denote their shape, lobing, markings, appendages, etc. Among the more common of these are *capitate*, referring to a spheroidal stigma, *bifid*, or two-lobed, *truncate*, when cut square off at the tip, *annular*, or ringed below the summit, *penicillate* or brush-like, *barbellate*, having minute barbs, etc.

POLLINATION

Pollination is the transfer of pollen from anther to stigma and the consequent germination thereon. It is a necessary step to fertilization.

When the pollen is transferred to the stigma of its own flower the process is called *Close* or *Self-pollination;* if to a stigma of another flower, *Cross-pollination*. If fertilization follows, these processes are termed respectively, *Close or Self-fertilization* and *Cross-fertilization*. Close-fertilization means in time ruination to the race and happily is prevented in many cases by (*a*) the stamens and pistils standing in extraordinary relation to each other, (*b*) by the anthers and pistils maturing at different times, (*c*) by the pollen in many cases germinating better on the stigma of another flower than its own.

The agents which are responsible for cross-pollination are the wind, insects, water currents, small animals, and man.

Wind-pollinated flowering plants are called **Anemophilous;** their pollen is dry and powdery, flowers inconspicuous and inodorous, as in the Pines, Wheat, Walnut, Hop, etc.

Insect-pollinated plants are called **Entomophilous.** These, being dependent upon the visits of insects for fertilization, possess brilliantly colored corollas, have fragrant odors, and secrete *nectar*, a sweet liquid very attractive to insects, which are adapted to this work through the possession of a pollen-carrying apparatus. Example: Orchids.

Plants pollinated through the agency of water currents are known as **Hydrophilous.** To this class belong such plants as live under water and which produce flowers at or near the surface of the same. Example: Sparganium.

Bird-pollinated plants are called **Ornithophilous.** Some plants like the Nasturtium and Honeysuckle are pollinated by humming birds. Other plants, as Aspidistra, are pollinated by snails and slugs when they are called **malacophilous.** These have dark colored flowers.

Before the pollen grain has been deposited upon the stigma and during its germination thereon, a series of events affecting both the pollen grain and the embryo sac occur which result in the ultimate formation of the male and female gametophytes.

MATURATION AND FERTILIZATION

(*In Angiosperms*)

Maturation of the Pollen Grain and Formation of the Male Gametophyte.—The substance of the microspore (pollen grain) divides into two cells, the *mother* and *tube cells* of the future male gametophyte. The nucleus of the mother-cell divides to form two sperm nuclei. Within the tube cell is found a tube nucleus embedded in protoplasm. Upon germinating the partition disappears and the thin endospore (*intine*), carrying within it the protoplasm in which are embedded the tube nucleus and two sperm nuclei, penetrates through a deficiency of the exospore (*exine*). The contents of the pollen grain at this stage is called the *male gametophyte.*

Maturation of the Embryo Sac and Formation of the Female Gametophyte.—The *nucleus* of the megaspore or embryo sac undergoes division until eight *daughter-nuclei* are produced which are separated into the following groups:

(*a*) Three of these nuclei occupy a position at the apex, the lower nucleus of the group being the egg or ovum, the other two nuclei being the *synergids* or *assisting nuclei.*

(*b*) At the opposite end of the sac are three nuclei known as the *antipodals* which apparently have no special function.

(*c*) The two remaining nuclei (*polar nuclei*) form a group lying near the center of the embryo sac which unite to form a single *endosperm* nucleus from which, after fertilization, the endosperm or nourishing material is derived. This stage of the embryo sac constitutes the *female gametophyte.*

Fertilization in Angiosperms.—After the pollen grain reaches the stigma, the viscid moisture of the stigma excites the outgrowth of the male gametophyte which bursts through the coats of the pollen grain forming a pollen tube. The pollen tube, carrying within its walls two sperm nuclei and one tube nucleus, penetrates through the loose cells of the style until it reaches the micropyle of the ovule,

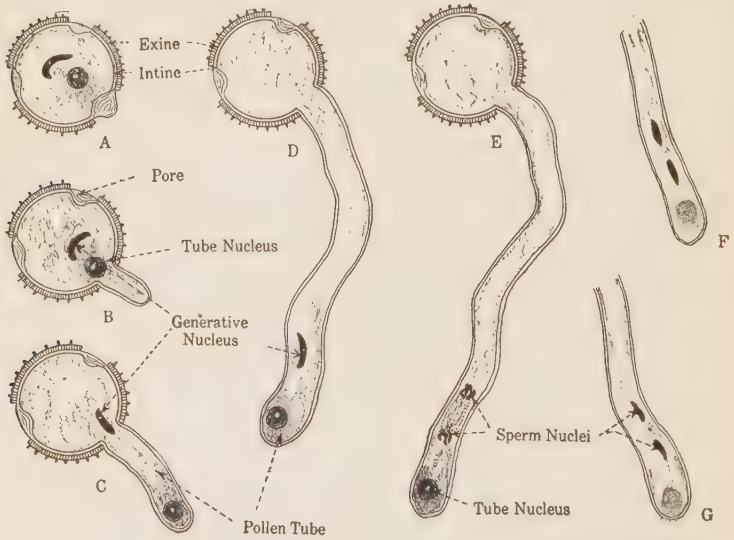

FIG. 173.—Stages in the germination of the pollen grain and development of the pollen tube. (*From Robbins, after Holman and Robbins, after Bonnier and Sablon.*)

then piercing the nucellus, it enters the embryo sac. The tip of the tube breaks and one of the sperm nuclei unites with the egg nucleus to form the *oöspore*. The oöspore develops at once into an embryo or plantlet which lies passive until the seed undergoes germination. The other sperm nucleus unites with the previously fused polar nuclei to form the endosperm nucleus which soon undergoes rapid division into a large number of nuclei that become scattered about through the protoplasm of the embryo sac. These accumulate protoplasm about them, cell walls are laid down, **endosperm** resulting.

FIG. 174.—Development of the female gametophyte in an angiosperm. *A*, lengthwise section through a pistil showing a single inverted ovule within the locule of the ovary. The embryo sac is in the center of the ovule surrounded by the nucellus (*N*) and the two integuments (I) better shown in *C*. Note how the pollen tube reaches and enters the micropyle of the ovule. *B* shows the development of the eight nuclei in the embryo sac. *C* shows the mature female gametophyte and the tip of the male gametophyte; the former containing eight nuclei and the latter containing only three. *AP*, antipodal nuclei; *E*, egg nucleus; *EN*, two polar nuclei fusing to form endosperm nucleus; *I*, integuments; *N*, nucellus; *S*, sperm nuclei. (*After Atwood.*)

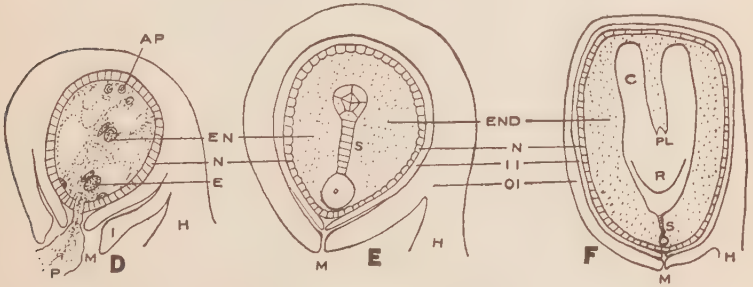

FIG. 175.—Development of the embryo. This figure is a continuation of the preceding. *D* shows the antipodal cells (*AP*) disappearing, and the fusion of the two sperm nuclei with the endosperm nucleus (*EN*) and the egg nucleus (*E*). The remains of the pollen tube (*P*) are seen in the micropyle (*M*). *E* shows the developing embryo with its suspensor (*S*) and the endosperm (*END*). *F* shows the young embryo and its parts. *C*, cotyledons; *PL*, plumule; *R*, root. Note that the embryo is surrounded by four coats. *END*, endosperm; *N*, nucellus; *II* and *OI*, inner and outer integuments. *H* is the hilum. (*After Atwood.*)

Development of the Embryo (*Dicotyledons*).—In the development of the embryo of a typical Dicotyledonous type, as seen in *Brassica* (the mustard genus), the oöspore, lying within the embryo sac, undergoes division and redivision to form a several celled filament. At the end of the filament farthest away from the micropyle of the ovule, unequal growth and differentiation takes place which eventu-

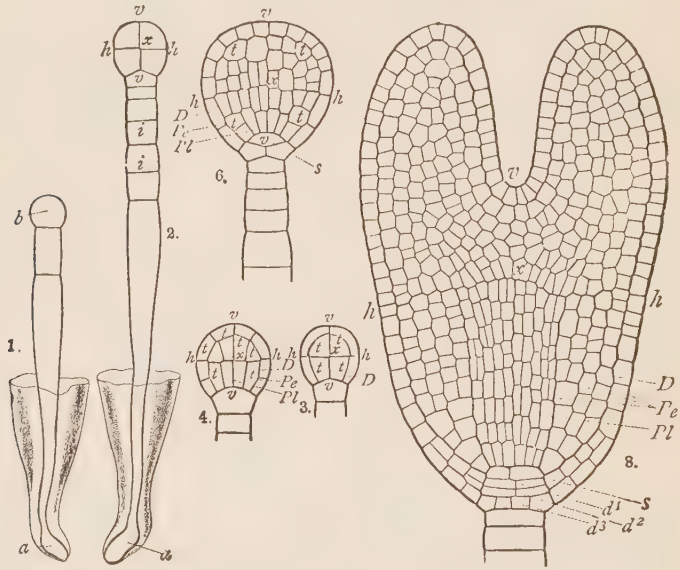

Fig. 176.—Successive stages, 1, 2, 3, 4, 6, 8, in the development of the embryo of *Brassica*. 1. Proembryo. 2. Octant stage. *x*, Octant. *i*, *i*, Suspensor. 3. Formation of dermatogen. 4. Differentiation of periblem and plerome. 6. Last cell or hypophysis, (*v*), of suspensor completes the dermatogen by division. 8. Inner part of *v*. d^1, d^2, Completes periblem. *v*, Region of stem apex. *h*, *h*. Bases of cotyledons. *D*, Dermatogen. *Pe*, Periblem. *Pl*, Plerome. (*From Small, after Kny.*)

ally produces the body or main part of the embryo. Just below this region, the cells of the filament develop into a suspensor whose basal cell is larger than the rest and directed toward the micropylar end of the embryo sac. The body of the embryo is formed as follows: The upper end cell of the axis of the young developing embryo divides to form 2 rows of four cells each. The upper row of 4 cells by unequal growth and repeated division form the terminal

epicotyl and 2 lateral cotyledons. The 4 cells of the lower row similarly form the hypocotyl.

Monocotyledons.—In the average Monocotyledon, the oöspore divides to form a short row of 3 cells. The basal cell which is the largest of the three does not divide. The middle cell of the row by repeated division and unequal growth of the cells, develops into a suspensor, a hypocotyl and a lateral epicotyl. The terminal cell, by repeated divisions and unequal growth forms the single cotyledon which is terminal on the axis of the embryo.

CHAPTER XIV

THE FRUIT

The fruit consists of the matured pistil (carpel or carpels) and contents, or ovarian portion thereof, but may include other organs of the flower which frequently are adnate to and ripen with it. Thus, in the Apples, Pears, and Quinces, the receptacle becomes thick and succulent, surrounds the carpels during the ripening process and forms the edible portion of these fruits. In Dandelion, Arnica, and many other members of the *Compositæ*, the modified calyx or *pappus* adheres to the ovary during its maturation into the fruit and renders the fruit buoyant. In *Gaultheria*, the calyx becomes fleshy, surrounds the ovary, reddens, and forms the edible part of the fruit. In *Physalis* the calyx enlarges considerably and encloses the ovary in an inflated colored bladder. Involucres frequently persist around and mature with the fruits. These may be membranous as in *Anthemis*, *Matricaria* and other *Compositæ*, leathery and prickly as in the Chestnuts, scaly woody cups (cupules) as in the Oaks, or foliaceous cups as in the Filberts. Occasionally, as in the Fig, Osage Orange, Mulberry, etc., the fruit may consist of the ripened flower cluster or inflorescence.

Fruit Structure

The Pericarp.—The *Pericarp*, or *seed vessel*, is the ripened wall of the ovary, and in general the structure of the fruit wall resembles that of the ovary, but undergoes numerous modifications in the course of development.

The number of cells of the ovary may increase or decrease, the external surface may change from soft and hairy in the flower to hard, and become covered with sharp, stiff prickles, as in the *Datura Stramonium* or Jamestown weed. Transformations in consistence may take place and the texture of the wall of the ovary may become

hard and bony as in the Filbert, leathery, as the rind of the Orange, or assume the forms seen in the Gourd, Peach, Grape, etc.

Frequently, as in the Apple, Pear, Quince, etc., the pericarp consists for the most part of other elements than the ripened ovarian wall and is then termed a *pseudocarp* or *anthocarp*.

The pericarp consists of three layers of different texture, viz.: *epicarp*, *mesocarp* and *endocarp*. The epicarp is the outer layer.

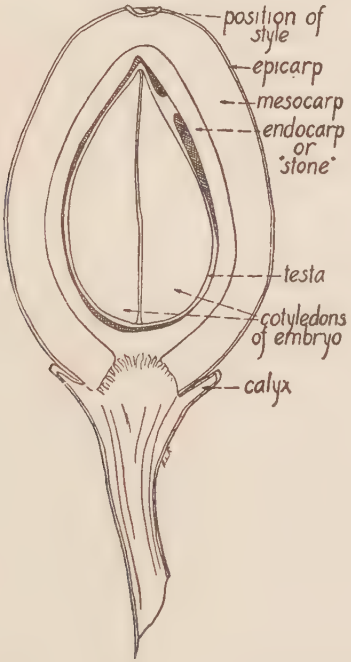

FIG. 177.—Fruit of Cherry (a drupe) as seen in median lengthwise section. (*After Robbins.*)

The mesocarp the middle, and the endocarp the inner layer. When the mesocarp is fleshy, as in the Peach, it is called the *sarcocarp*.

When the endocarp within the sarcocarp is hard, forming a shell or stone, this is termed a *putamen*.

Sutures.—The *ventral suture* is a line formed by the coherent edges of a carpellary leaf. The *dorsal suture* is the mid-rib of the

carpel. *Parietal sutures* are lines or furrows frequently visible on the walls of fruits, formed by the ripening of a compound ovary. They occur between its dorsal sutures and indicate the places of union between adjacent septa or of two parietal placentæ.

Valves.—These are the parts into which the mature fruit separates to permit the escape of the seeds. Depending upon the number of these the fruit is said to be *univalved*, *bivalved*, *trivalved*, etc.

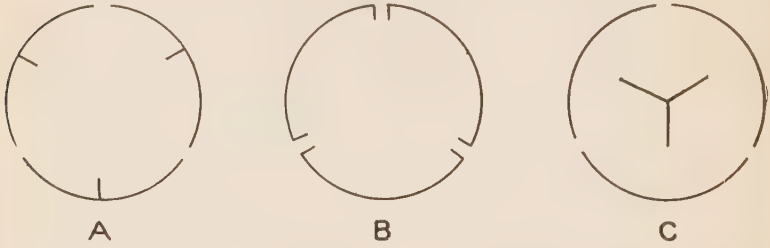

FIG. 178.—Diagrams illustrating three forms of valvular dehiscence. A, Loculicidal dehiscence showing each carpel split along its midrib or dorsal suture, the dissepiments remaining intact; B, septicidal dehiscence, in which splitting took place along the partitions; C, septifragal dehiscence, in which the valves broke away from the partitions.

Dehiscence.—This is the opening of the pericarp to allow the seeds to escape.

Fruits are either *Dehiscent* or *Indehiscent* according as to whether they open to discharge their seeds spontaneously when ripe (**dehiscent**), or decay, thus freeing the seeds, or retain their seeds, the embryo piercing the pericarp in germination (**indehiscent**). Dehiscent fruits open regularly, or normally, when the pericarp splits vertically through the whole or a part of its length, along sutures or lines of coalescence of adjacent carpels. Legumes usually dehisce by both ventral and dorsal sutures. Irregular or abnormal dehiscence has no reference to normal sutures, as where it is **transverse** or **circumscissile,** extending around the capsule either entirely or forming a hinged lid, as in *Hyoscyamus*, or detached.

Dehiscence is called **porous** or **apical** when the seeds escape through pores at the apex, as in the Poppy; **valvular,** when valve-like orifices form in the wall of the capsule.

There are three kinds of valvular dehiscence, viz.: septicidal, loculicidal and septifragal. **Septicidal dehiscence** is that form in which the constituent carpels of a fruit become disjoined, and then open along their ventral suture, as in *Colchicum*.

Loculicidal dehiscence, or dehiscence into loculi or cells, is the form which is seen when each component carpel splits down its

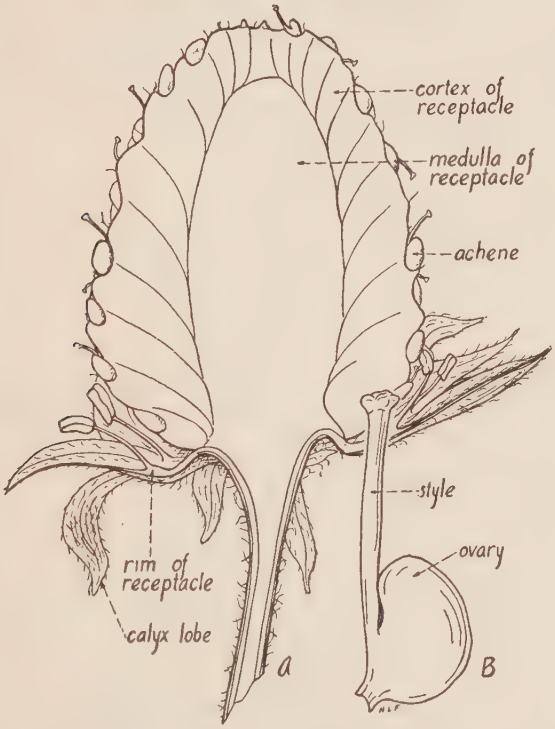

FIG. 179.—*A*. The aggregate fruit of the Strawberry as seen in median longitudinal section, × 2½. *B*, A single achene. The greater bulk of this fruit consists of a fleshy receptacle. Partially imbedded in the surface of this receptacle are numerous seed-like bodies which represent true fruits or achenes. (*After Robbins.*)

dorsal suture, and the dissepiments or partition walls separating the ripened carpels remain intact, as in *Cardamon*. **Septifragal dehiscence** is that form in which there occurs a breaking away of the valves from the septa or partitions, as in Stramonium.

Classification of Fruits (according to structure).—**Simple fruits** result from the ripening of a single pistil in a flower.

Aggregate fruits are the product of all the carpel ripenings in one flower, the cluster of carpels being crowded on the ripened receptacle forming one mass, as in the Raspberry, Blackberry, and Strawberry.

Multiple fruits are those which are the product of the ripening of a flower cluster instead of a single flower.

Simple and Compound fruits are either Dry or Fleshy. The first may be divided into Dehiscent, those which split open when ripe; and Indehiscent, those which do not.

Simple Fruits:

Dry	I. Capsular (dehiscing).
	II. Schizocarpic (splitting).
	III. Achenial (indehiscent).
Succulent	IV. Baccate (berries).
	V. Drupaceous (stone fruits).

The **capsular** fruits include all of those, whether formed of one or more carpels, which burst open to let their seeds escape.

Schizocarpic or splitting fruits are those in which each carpel or each half carpel (in *Labiatæ*) splits asunder from its neighbor and then falls to the ground. The split portion is one-seeded.

Achenial fruits are dry, one-celled, one-seeded and indehiscent at the time of final ripening.

Baccate fruits are such in which the endocarp always and the mesocarp usually becomes succulent and so the seeds lie in the pulp formed by the endocarp or endocarp and mesocarp combined.

Drupaceous fruits are those in which the endocarp is always fibrous or stony in consistence, while the mesocarp is more or less succulent. The endocarp may become cuticularized as in the Apples. The mesocarp may form stone cells lying in the midst of soft parenchyma cells as in Pears; it may become hardened and thickened by lignin deposits to form fibers as in the Cocoanut, or it may become swollen and soft-succulent as in Peaches, Cherries, etc.

I. **Capsular Fruits.**—These may be simple, when composed of one carpel as the follicle and legume, or compound, when

composed of two or more carpels as the capsule, pyxis, regma, siliqua or silicule.

The **Follicle** or pod [Fig. 180 (1)] is a dry, simple, capsular fruit formed of a single carpel which dehisces by one suture. This is

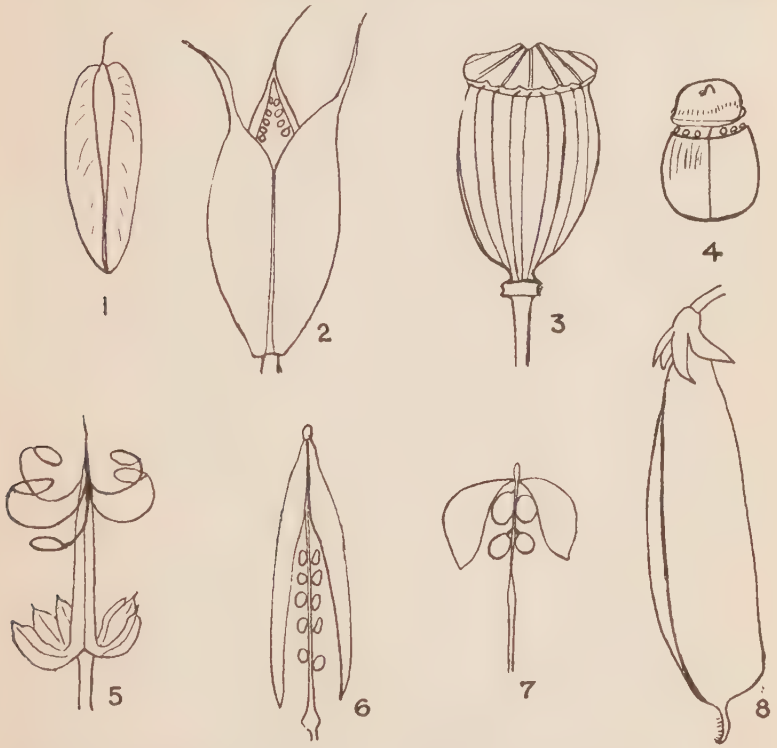

FIG. 180.—Types of capsular fruits. 1, Pod of Aconite; 2, Capsule of Colchicum showing septicidal dehiscence; 3, capsule of poppy, having porous dehiscence; 4, pyxis of Henbane; 5, dehiscing regma of Geranium; 6, siliqua of Celandine showing valves opening from below upward; 7, silicule of Cochlearia; 8, Legume of Pea.

usually the ventral suture as in *Aconite*, *Staphisagria*, *Larkspur* and some other *Ranunculaceæ*, but may be the dorsal suture as in *Magnolia*.

A **Legume** is a dry, simple, capsular fruit formed of a single carpel and dehiscent by both ventral and dorsal sutures. Examples:

Peas, Beans, etc. The legume is typical of most *Leguminosæ*, Fig. 180 (8).

A **Capsule** is a fruit formed of two or more carpels which dehisce longitudinally or by apical teeth or valves. Examples: *Cardamon*, Poppy, *Iris*, etc., Fig. 180 (2 and 3).

A **Pyxis** or **Pyxidium** is a capsular fruit formed of two or more carpels that dehisce transversely. Examples: *Hyoscyamus*, *Portu-*

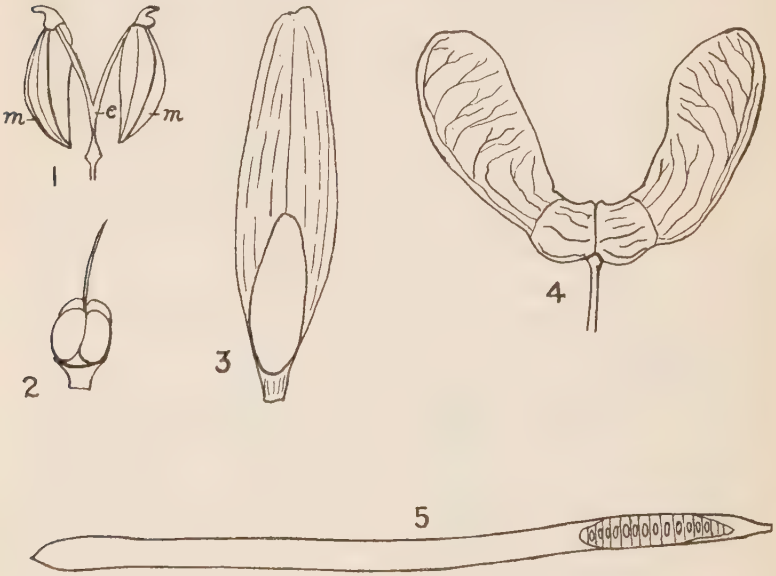

FIG. 181.—Schizocarpic fruits. 1, Cremocarp of Fennel, composed of two mericarps (*m*) and a split carpophore (*c*); 2, carcerulus of the Bugle; 3, one-carpelled samara of the Ash; 4, double samara of the maple; 5, loment of purging cassia, a portion of the pericarp being removed to show chambers, each containing a single seed.

laca. The upper portion forms a lid which fits upon the lower pot-like portion, Fig. 180 (4).

A **Regma** is a capsular fruit of two or more carpels that first splits into separate parts and then each of these dehisces. This type of fruit is typical of *Hura crepitans* (Sandbox), *Pelargonium* and *Geranium*, Fig. 180 (5).

A **Siliqua** is a long, slender, one or two-celled capsule, often with a spurious membranous septum (when two-celled) and two persistent parietal placentæ, the valves opening from below upward. Examples: *Chelidonium* and Wallflower, Fig. 180 (6).

A **Silicule** is a short siliqua in which the length is never much greater than the breadth. Example: *Cochlearia*, Fig. 180 (7).

II. **Schizocarpic Fruits.**—A **Carcerulus** or **Nutlet** is the typical fruit of the *Labiatæ*, but is also seen in the *Boraginaceæ*. The ovary that has become four-celled at the time of flowering matures into four little pieces which split asunder lengthwise. Each split part is composed of one-half of a ripened carpel, Fig. 181 (2).

A **Cremocarp** is the characteristic splitting fruit of the *Umbelliferæ* family. It consists of two inferior akenes or mericarps separated from each other by a forked stalk called a *carpophore*. These mericarps usually cling to the forks of the carpophore for a time after the cremocarp splits, but sooner or later fall, Fig. 181 (1).

A **Samara** is a winged splitting fruit. It may be one-carpelled as in the Elm, Ash, Tulip Poplar and Wafer Ash or two-carpelled as in the Maples, Fig. 181 (3 and 4).

A **Lomentum** or **Loment** is a modified legume that is separable transversely into one-seeded portions. Seen in Acacia, Peanut, Tamarind, *Entada scandens*, *Cathartocarpus Fistula*, *Desmodium*, etc., of *Leguminosæ*, Fig. 181 (5).

III. **Achenial Fruits** (all indehiscent).—The **Akene** is a dry, one-chambered, indehiscent fruit, in which the pericarp is firm and not united with the seed, the style remaining in many cases as an agent of dissemination, Fig. 182 (1). The latter may be long and feathery as in *Clematis* or be hooked. Examples of akenes: Fruits of the *Compositæ*, *Anemone*, etc. The **Hip** of the Roses consists of a number of akenes in a ripened concave receptacle.

The **Utricle** is like the akene, except that the enveloping calyx is loose and bladder-like. Example: *Chenopodium*, Fig. 182 (3).

A **Caryopsis** or **Grain** is similar to an akene but differs from it by the pericarp being always fused with the seed coat. This fruit is more likely than any other to be mistaken for a seed. Examples: Wheat, Corn, Barley, Oats and other members of the *Gramineæ*, Fig. 182 (2).

A **Nut** or **Glans** is a one-celled, one-seeded fruit with a leathery or stony pericarp. Examples: Oaks, Beeches, Chestnuts, Alders and Palms, Fig. 182 (4).

IV. **Baccate Fruits** (Succulent fruits in which the endocarp is always succulent and the mesocarp sometimes).—The **Berry** is a small fleshy fruit with a thin membranous epicarp and a succulent interior in which the seeds are imbedded. Examples: Capsicum, Tomato, Belladonna, Grape, Currant, etc.

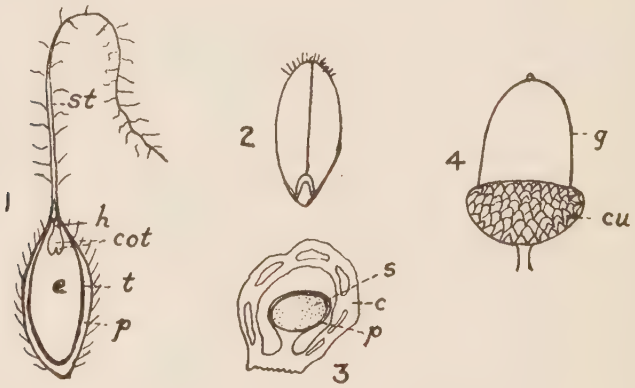

FIG. 182.—Achenial fruits. 1, Akene of Pulsatilla cut vertically, showing adherent feathery style (*st*), pericarp (*p*), testa (*t*), endosperm (*e*), hypocotyl (*h*) and cotyledons (*cot*) the last two structures making up the embryo; 2, caryopsis of wheat showing beard of hairs above and position of embryo of seed below; 3, utricle of Chenopodium cut vertically to show calyx (*c*), pericarp (*p*) and seed (*s*) regions; 4, nut of an oak consisting of a glans (*g*) and cupule (*cu*).

An **Uva** is a berry from a superior ovary. Examples: Belladonna, Egg-plant, Tomato, Fig. 183 (1).

A **Bacca** is a berry from an inferior ovary. Examples: Gooseberry, Honeysuckle, Currant.

The **Pepo** or **Gourd Fruit** is a baccate fruit of large size which has developed from an inferior ovary. It is fleshy internally and has a tough or very hard rind. Examples: Fruits of the *Cucurbitaceæ* and the Banana, Fig. 183 (2).

The **Hesperidium** is a large thick-skinned, succulent fruit with seeds embedded in the pulp but from a superior ovary. Examples: Orange, Grape-fruit, Lemon, etc. In each of these there is to be

noted a glandular leathery epicarp, a sub-leathery mesocarp and an endocarp in the form of separate carpels. From the endocarp hairs grow inward into the carpellary cavities and become filled with succulence. The seeds lie amid the hair cells, Fig. 183 (3).

V. **Drupaceous Fruits** (Succulent fruits in which the mesocarp is more or less succulent, but the endocarp leathery or stony).—A **Drupe** is a one-celled, one-seeded, drupaceous fruit such as the fruit of the Plum, Peach, Prune, Sabal, Rhus, Piper, Cherry, etc.,

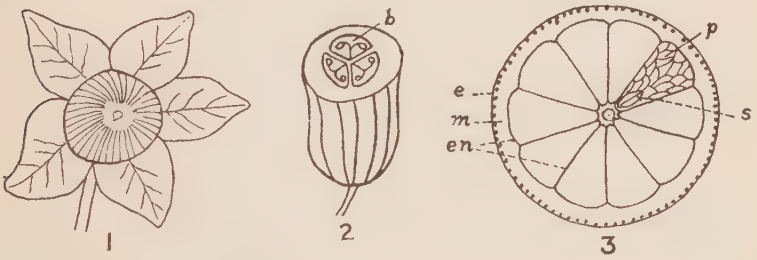

FIG. 183.—Baccate fruits. 1, Berry (uva) of Belladonna with adherent calyx; 2, Pumpkin, cut transversely illustrating a pepo fruit; (*h*), a locule; 3, hesperidium fruit of the Orange cut transversely showing epicarp (*e*), mesocarp (*m*), endocarp (*en*), pulp (*p*), and seed (*s*).

whose endocarp or putamen is composed wholly of stone cells or stone cells and sclerenchyma fibers, Fig. 184 (1).

The **Pome** is a fleshy, drupaceous fruit, two or more celled with fibrous or stony endocarp, the chief bulk of which consists of the adherent torus. Quince, Apple and Pear are examples. The carpels constitute the core, and the fleshy part is developed from the torus, Fig. 184 (2).

Aggregate Fruits.—An **Etærio** consists of a collection of little drupes or of achenes on a ripened torus of a single flower. Examples: Raspberry, Blackberry, Strawberry, etc., Fig. 184 (3 and 4).

Multiple Fruits.—The **Syconium** is a multiple fruit consisting of a succulent, hollow torus enclosed within which are akene-like bodies, products of many flowers. Example: Fig. 185 (1).

The **Sorosis** is represented by the Mulberry, Osage Orange, etc., the grains of which are not the ovaries of a single flower, as in the Blackberry, but belong to as many separate flowers. In the Pine-

apple all the parts are blended into a fleshy, juicy, seedless mass, and the plant is propagated by cuttings.

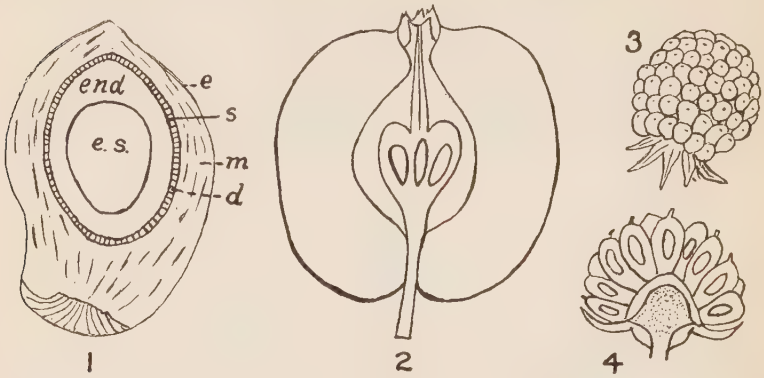

FIG. 184.—1, Drupe of cocoanut cut vertically, showing epicarp (*e*), mesocarp (*m*), stony endocarp (*d*), seed coat (*s*), endosperm (*end*), and embryo sac cavity (*e.s.*) which in the mature seed contains a nutritive fluid. 2, Pome of an apple cut vertically to show core composed of 5 ripened carpels and flesh of matured torus. 3, Etærio of raspberry. 4, Same, cut vertically to show arrangement of the little drupes on fleshy receptacle.

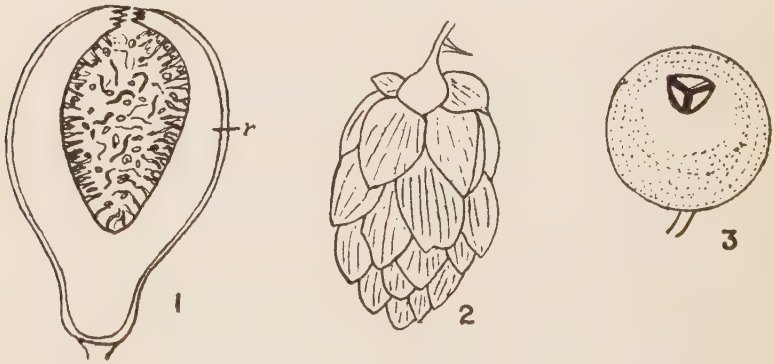

FIG. 185.—Multiple fruits. 1, Syconium of Fig cut vertically to show hollowed out receptacle (*r*) of ripened flower cluster; 2, strobile of the hop; 3, galbulus of Juniper.

The **Strobile** or **Cone** is a scaly, multiple fruit consisting of a scale-bearing axis, each scale enclosing one or more seeds. The name is applied to the fruit of the Hop, Fig. 185 (2), and also to

the fruit of the *Coniferæ* in which the naked seeds are borne on the upper surface of the woody scales.

A **Galbulus** is a more or less globular multiple fruit formed of fleshy connate scales, as in Juniper, Fig. 185 (3).

Histology of a Capsule, Vanilla.—The vanilla fruit is a one-celled capsule formed by the union of three carpellary leaves and dehiscing by two unequal longitudinal valves.

Microscopic Appearance of a Transverse Section.—Passing from periphery toward the center, the following structures present themselves:

1. **Epicarp,** consisting of *epidermis* and *hypodermis*. The *epidermis* consists of a layer of thick-walled epidermal cells whose outer walls show the presence of a thin yellow cuticle. Stomata are present in this tissue. The epidermal cells contain protoplasm and brownish bodies. Some also contain small prisms of calcium oxalate and a few, vanillin crystals. The *hypodermis* is composed of one to several layers of collenchymatic cells with dark-colored contents. Its cells are somewhat larger than those of the epidermis and thicker-walled.

2. **Mesocarp,** a broad region of somewhat loosely arranged, large, thin-walled parenchyma cells becoming smaller in the inner zone of this region. Most of these cells contain brownish contents but some possess long raphides of calcium oxalate. If the section be mounted in phloroglucin solution (5 per cent.) and a drop of strong sulphuric acid is added, a carmine-red color will be observed showing the presence of vanillin in this region. Several closed collateral bundles will be seen coursing through the mesocarp.

3. **Endocarp,** an irregular line of inner epidermal cells which is differentiated into two regions, the interplacental region and the placental region. The interplacental (inner) epidermis shows its cells elongated into numerous thin-walled glandular hairs which contain an abundance of balsam; the placental region covers the six bifid *placentæ* which extend into the cavity of the capsule. Its (inner) epidermis is composed of mucilaginous cells.

4. **Seeds.**—These are minute blackish bodies attached to the placental twigs of the placentæ. Some of them may have been torn off in cutting the section.

Histology of a Typical Mericarp, Fœniculum.—This five-angled fruit, in transverse section, shows a concave *commissural* and convex *dorsal surface*. Passing from the surface toward the center we note:

1. *Epicarp*, or outer covering tissue, composed of colorless epidermal cells and small stomata. The epidermal cells in cross-section appear rectangular, while in surface view they are both polygonal and rectangular.

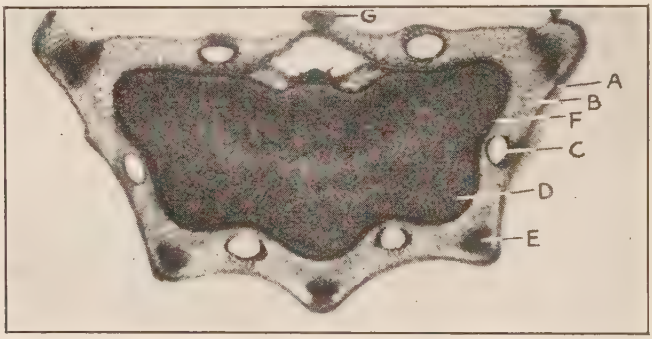

FIG. 186.—Photomicrograph of a transverse section of a mericarp of *Fœniculum vulgare*, showing epicarp (*A*), mesocarp (*B*), endocarp (*F*), vitta (*C*), endosperm of seed (*D*), carpophore (*G*) and fibro-vascular bundle in primary rib (*E*). (Highly magnified.)

2. *Mesocarp*, of several layers of thin-walled, colorless, isodiametric cells, beneath which are two to several additional layers of thicker-walled cells with brownish walls. Through the angles or rib portions of the mesocarp extend the fibro-vascular bundles. Between each fibro-vascular bundle and the tip of each rib will be found a zone of collenchyma cells. In the mesocarp between each two ribs on the dorsal side occurs a single **vitta** or *oil tube* which is lined with a layer of brownish polygonal cells. These vittæ contain the official oil of fennel. Two vittæ generally occur in the mesocarp of the commissural side although four are reported to have been found in this region of some fennel fruits.

3. *Endocarp*, a narrow layer of cells, transversely elongated, except over the regions of bundles where they may be seen elongated in several directions.

4. *Spermoderm or Seed Coat*, consisting of a layer of somewhat broadened epidermal cells attached to the endocarp and several layers of collapsed cells which are only well defined in the region of the *raphe*.

5. *Endosperm*, a central mass of more or less polygonal cells containing aleurone grains and oil globules. Each aleurone grain contains a rosette aggregate of calcium oxalate and one or two globoids.

6. *Embryo*, embedded in the endosperm of the upper region of the seed.

CHAPTER XV

THE SEED

A *seed* is a fertilized and matured ovule containing an embryo.

The **embryo** is a young plant in a dormant state of existence. When fully developed within the seed it consists of four principal parts: the *caulicle* or embryonic stem, the *plumule* or embryonic bud, the *radicle* or embryonic root and one, two or more seed leaves called *cotyledons*. The plumule is at the summit of the caulicle and consists of the young growing apex of the caulicle with delicate rudimentary leaves enveloping it. The radicle is a continuation of the lower end of the caulicle. It develops, upon the sprouting of the seed, the primary or first root of the seedling. The cotyledons frequently are carried above the soil, upon germination, and there function to build up food for the seedling plantlet until the latter has developed foliage leaves. In some seeds the cotyledons contain stored food which is used by the embryo as it develops into the seedling plantlet.

All that portion of an embryo plantlet above the cotyledons is termed the *epicotyl* and all that part below the cotyledons, the *hypocotyl*. The purpose of the seed is to insure the continuation and distribution of the species. It is therefore an organ of reproduction. Like all other organs of the plant, seeds exhibit irritability, nutrition, respiration and growth. These, in the dry seed, are in the state of reduced activity. When properly stored, seeds may live for one year, as those of Aconite and Larkspur, or one to three years, as those of the Grass family, or two to five years, as those of the Rose and Mallow families, or rarely 5 to 75 years as those of the Bean and Pea family.

Seed Structure.—The average seed shows one or two seed coats that enclose an **embryo** which fills the seed cavity; the seed is then termed *exalbuminous*, as in beans, peas and other leguminous seeds;

or between the seed coat and embryo reserve food may be stored, and the seed is then termed *albuminous*, as in the cereals, castor bean, etc. The stored food in or around the embryo may consist of starch and protein (pea, bean), or starch, protein and oil (peanut), or oil and protein and active medicinal principle (castor and croton), or of hard reserve cellulose and protein (date, nux vomica, coffee, ivory-nut, palm-nuts). The seed coats, corresponding to those of the ovule, are one or two in number. If but one seed coat is present

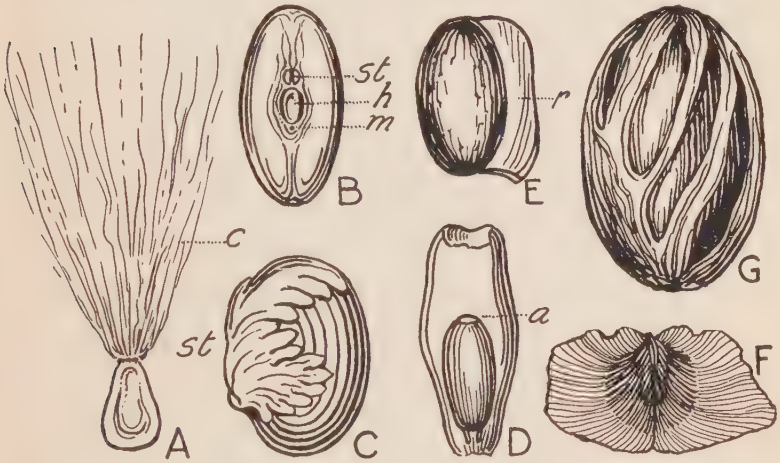

FIG. 187.—Appendages of seeds. *A*, coma (*c*) on milkweed (*Asclepias*); *B*, strophiole (*st*) on bean (*Phaseolus*) *h*, hilum, *m*, micropyle; *C*, strophiole on Corydalis aurea; *D*, aril on white water-lily (*Castalia*); *E*, projecting raphe (*r*) on pitcher plant (*Sarracenia purpurea*); *F*, wing on trumpet creeper (*Tecoma radicans*); *G*, arillode ("mace") on nutmeg. *A*, *B*, and *G* from nature; *C-F*, redrawn from Gray. (*After Gager.*)

it is termed the **spermoderm.** If two are present, the outer one is called the **testa,** and the inner one the **tegmen.** The testa, or outer seed shell, differs greatly in form and texture. If thick and hard, it is crustaceous; if smooth and glossy, it is polished; if roughened, it may be pitted, furrowed, hairy, reticulate, etc.

The testa may often present outgrowths or seed appendages whose functions are to make the seeds buoyant, whereby they may be disseminated by wind currents. Examples of these are seen in the Milkweed, which has a tuft of hairs at one end of the seed called a

Coma, and in the official **Strophanthus,** which has a long bristle-like appendage attached to one end of the seed and called an **awn.** The wart-like appendage at the hilum of some seeds, as in Castor Oil Seed, is called the **Caruncle** or **Strophiole.**

The tegmen or inner coat surrounds the nucellus closely and is generally soft and delicate.

A third integument, or accessory seed covering the outside of the testa, is occasionally present and is called the **Aril.** Examples: *Evonymus* (succulent) and Cardamon (dry).

When such an integument arises from the dilatation of the micropyle of the seed, as in the Nutmeg, it is known as an **Arillode.**

The **Kernel** consists of tissue containing albumen, when this substance is present, and the *embryo.* Albumen is the name given the nutritive matter stored in the seed. The funiculus or seed stalk is usually absent in the official seeds. The scar left by its separation is called the **hilum.** When the funiculus is continued along the outer seed coat, it is called the **raphe.**

MODE OF FORMATION OF DIFFERENT TYPES OF ALBUMEN

If the fertilized egg-cell within the embryo sac segments and grows into the embryo and, stretching, fills up the cavity without food material laid down around it, it happens that the nutritive material lingers in the cells of the nucellus, pressing around the embryo. This nutritive material is called *Perispermic albumen.* The tissue of the seed containing it is called the **Perisperm** and represents the ripened nucellus of the ovule. Seen in the *Polygonaceæ* or Buckwheat family, etc.

In by far the greater number of Angiosperms, the endosperm nucleus, after double fertilization, divides and redivides, giving rise to numerous nuclei imbedded in the protoplasm of the embryo sac, outside of the developing embryo. Gathering protoplasm about them selves and laying down cell walls they form the **endosperm** tissue outside of the embryo. Into this tissue food is passed constituting the *Endospermic albumen.*

In the Arrowroot family (*Marantaceæ*), the Pepper family (*Piperaceæ*), etc., nutritive material is passed into the nucellar cells causing them to swell up, while to one side a small patch of endosperm

tissue accommodates a moderate amount of nourishing substance, thus resulting in the formation of abundant **perisperm** and a small reduced **endosperm.**

Exalbuminous seeds are those in which the albumen is stored in the embryo during the growth of the seed. Such seeds show the fleshy embryo taking up all or nearly all the room within the seed coat. Examples: **Physostigma, Amygdala,** etc.

Albuminous seeds are those in which the nourishment is not stored in the embryo until germination takes place. Such seeds show a larger nourishing tissue region and a smaller embryo region. Examples: **Nux Vomica, Myristica, Colchicum,** etc.

Gross Structure of a Monocotyl Seed (*With fruit wall attached*), *Indian Corn.*—The ripened seed of Indian Corn is surrounded by a thin, tough pericarp which is firmly adherent to and inseparable from the *spermoderm* or seed coat. Because of this fact, while in reality a fruit called a caryopsis or grain, this structure is sometimes erroneously termed a seed.

The mature grain of most varieties of Indian Corn is flattened and somewhat triangular in outline, the summit being broad and the base comparatively narrow. The summit is indented and often marked by a small point which represents a vestige of the style. The base or "tip" region marks the part of the grain which was inserted into the cob. Upon it may be found papery chaff, representing parts of the pistillate spikelets. The groove noted on the broader surface indicates the position of the embryo.

Histology of the Indian Corn Seed (*With fruit wall attached*).—If a longitudinal section be cut through the lesser diameter of a soaked grain, the following histologic characteristics will be observed:

1. The *Pericarp* or ripened ovarian wall which, alike with all other grains, adheres firmly to the wall of the seed forming a portion of the skin of the grain. The pericarp comprises an outer epicarp of elongated cells with thin cuticle, a mesocarp of thicker walled cells without, becoming thinner within, and a layer of tube cells.

2. The *Spermoderm* or seed coat, a single layer of delicate elongated cells.

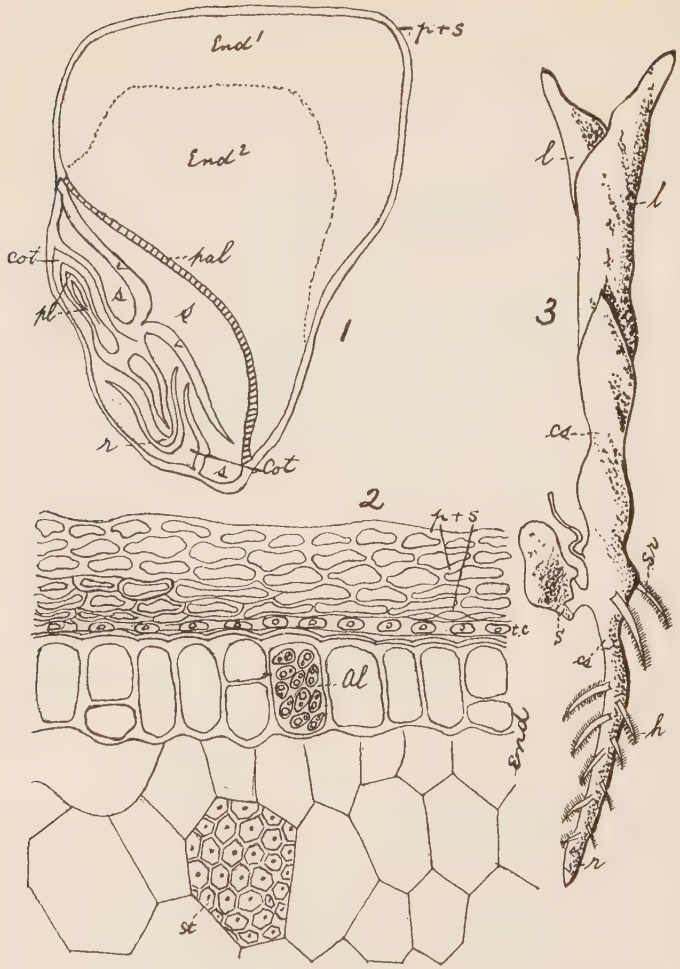

FIG. 188.—Indian Corn grain and seedling. 1, Median longitudinal section through lesser diameter of grain of corn showing fruit wall (pericarp) and adherent seed coat (spermoderm) $p + s$; horny endosperm (*end*¹); starchy endosperm (*end*²); palisade layer (*pal*) scutellum (*s*) with vascular tracts (*v*); cotyledonary sheath (*cot*); radicle (*r*) and plumule (*pl*). 2. Transverse section of a representative portion of outer region of corn grain showing pericarp (*p*) and spermoderm (*s*) with tube cells (*t.c.*); endosperm (*end*) with an outer layer of aleurone cells containing aleurone grains (*al*) and an inner starch parenchyma zone (*st*). 3. Young seedling showing first leaves (*l*); primary root (*r*) bearing secondary roots (*sr*) with root hairs (*h*); cotyledonary sheath (*cs*) and seed coat (*s*).

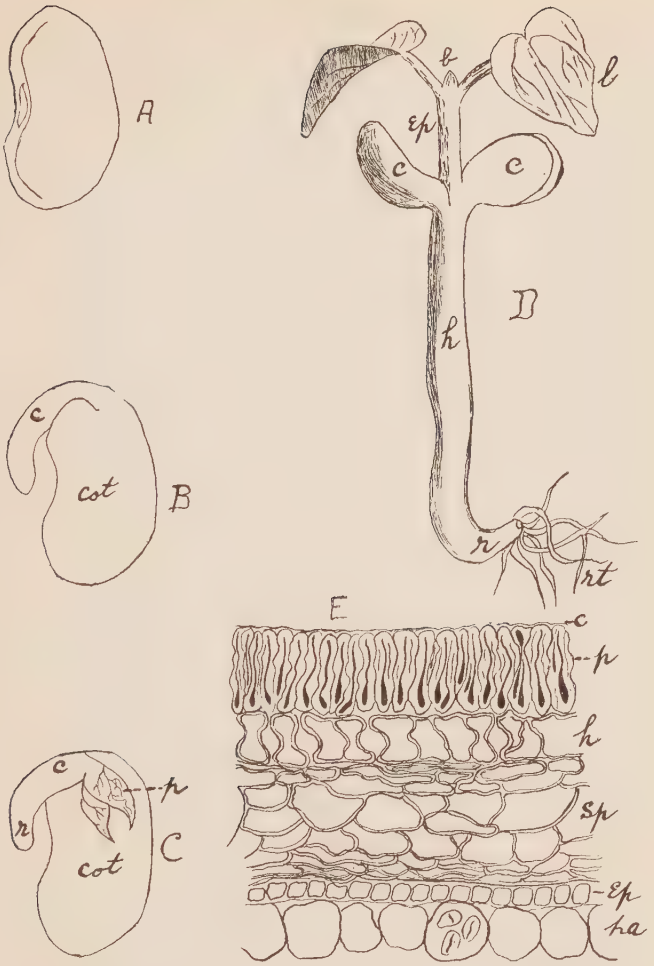

FIG. 189.—Lima Bean. *A*, seed showing scar (hilum); *B*, embryo after removal of seed coat showing one cotyledon (*cot*) and caulicle (*c*); *C*, embryo after removal of one of the cotyledons showing the second cotyledon (*cot*), plumule (*p*), caulicle (*c*), and radicle (*r*); *D*, young seedling showing epicotyl (*ep*) bearing first pair of green leaves (*l*) and a terminal stem bud (*b*); cotyledons (*c*), hypocotyl (*h*) with first root (*r*) and rootlets (*rt*); *E*, cross section of representative portion of seed showing cuticle (*c*), palisade cells (*p*), column cells (*h*) and spongy parenchyma (*sp*) of spermoderm; epidermis (*ep*) and parenchyma (*pa*) of mesophyll of cotyledon (magnified).

3. The *Perisperm*, another layer directly underneath the Spermoderm, difficult to distinguish without special treatment, and representing the ripened nucellar tissue of the ovule.

4. The *Endosperm* or nourishing tissue, consisting of: (*a*) The Aleurone Layer, for the most part a single row of cells, containing aleurone grains. Some of the cells may be seen to be divided by tangential partitions. (*b*) Starch Parenchyma, consisting of two regions: an outer horny zone composed of cells containing for the most part polygonal starch grains and oil droplets; and an inner mealy zone of cells with mostly rounded starch grains.

5. The *Embryo*, consisting of a single shield-shaped *cotyledon* adjoining the endosperm, the *plumule* or rudimentary bud at the end of the *caulicle* or rudimentary stem and the *radicle* or rudimentary root, with its tip covered by a root cap. Continuous with the root cap is a root sheath or *coleorhiza*. The cotyledon or seed leaf consists of two parts: the *scutellum* which lies next to the endosperm, and is an organ of absorption, and the *sheathing* portion which surrounds and protects the rest of the embryo.

The embryo contains oil and proteids, but no starch.

If a similar longitudinal section of a soaked grain be mounted in dilute iodine solution, the contents of the aleurone cells will be colored yellow indicating their proteid nature, while the starch grains will take on a blue to violet coloration. The endosperm will be observed taking up most of the room within the seed coat. The contents of its cells are not baled out to the embryo until after germination begins. Indian Corn is therefore an *albuminous seed*.

A MONOCOTYL SEEDLING

Germination.—When any viable seed is planted in suitable soil, and furnished with oxygen and water and a certain degree of heat, *germination* takes place. In the presence of moisture, etc., the seed swells, the ferments present within the cells of the endosperm then change the insoluble proteid, starch, and oil to soluble materials, which, in the case of Indian Corn, are absorbed in solution by the scutellum which bales this nourishment out to other parts of the growing embryo, there to be used in part in constructing new tissues, and in part to be consumed by oxidation or respiration. The process

of respiration or breathing takes place when the plant takes in oxygen and gives off carbon dioxide. The oxygen oxidizes the food materials within the tissues with an accompanying release of energy, which is necessary to life and growth.

The combined pericarp and spermoderm bursts opposite the tip of the radicle, and the radicle, piercing through the cotyledonary sheath, protrudes. The cleft in the coat lengthens to the point opposite the tip of the plumule, which also protrudes after bursting through she cotyledonary sheath. The radicle, next, grows downward into the lotl forming the primary root, and develops upon itself secondary or atieral roots, all of which give rise to root-hairs just above their root caps. Additional lateral roots emerge above the scutellar region which ere long attain the size of the first or primary root. The caulicle, carrying upon its tip the plumule, elongates and forms the stem; the leaves of the plumule spread out and turn green to function as foliage leaves. The perforated cotyledonary sheath grows out surrounding both the root and the stem for a portion of their length. By this time all or nearly all of the nourishment stored in the endosperm has been absorbed and assimilated by the young seedling and the coat and scutellum, left behind, gradually decay and disappear. The root-hairs absorb nourishment from the soil, the green leaves build up carbohydrates, prop-roots make their appearance at the first node (joint) above ground, and the seedling grows larger.

Gross Structure of a Dicotyl Seed, *Phaseolus lunatus* (Lima Bean). The Lima Bean Seed shows a flattened-ovate to somewhat reniform outline. Externally it exhibits a polished seed coat which is perforated on its basal side by a minute pore called the *micropyle* or *foramen*. Just below this pore will be noted the *hilum* or scar which represents the point of detachment from the *funiculus* or stalk, which connected the seed during its growth with the wall of the fruit. Upon soaking the seed in water it is possible to remove the *seed coat* or *spermoderm*. This done, the embryo will be exposed. The *two fleshy cotyledons* are first seen. Upon spreading these out, convex sides down, the rest of the embryo, consisting of a thin leafy structure surrounding a bud and called the *plumule*, the *caulicle* or rudimentary stem, and in line with the latter, the *radicle*, or rudimentary root, will be seen.

Histology of the Lima Bean Seed.—In transverse sections, the following microscopic structures will be evident:

1. *Spermoderm* of three regions, viz.; Palisade cells, Column cells, and Spongy Parenchyma. The palisade cell layer is composed of vertically elongated, thick-walled cells which are covered on their outer faces by a clear glistening cuticle. The column cells, found forming a layer directly beneath the palisade zone, are hour-glass-shaped.

The *Spongy parenchyma* forms a zone of several layers of thin walled parenchyma cells, the cells of the outer and inner layers being considerably smaller than the middle layers.

2. *Embryo*, the two cotyledons of which make up the greatest bulk. These are composed of an epidermis covering over a region of mesophyll. The mesophyll is constituted of moderately thick-walled cells which contain ellipsoidal and kidney-shaped starch grains up to 65μ in length. A conspicuous branching cleft will be seen in the larger grains.

In the Lima Bean, the nourishment is stored in the embryo during the growth of the seed. It is, therefore, *exalbuminous*.

CHAPTER XVI

THE CLASSIFICATION AND NAMING OF PLANTS

The classification and naming of plants belongs to that department of Botany called Taxonomy, a name which was derived from two Greek words, *taxis*, arrangement, and *nomos*, law.

PRINCIPLES OF CLASSIFICATION

The modern classification of plants is an attempt to arrange plants in groups based upon their natural relationship or genetic affinities. The basis of all modern classification alike of plants and animals is the theory of organic evolution.

Organic evolution presumes that all organisms living to-day have descended from preexisting organisms either by direct descent or by common ancestry. Sufficient evidence has been brought forth during the past century to substantiate plant evolution. The sources of this evidence have been found in part through the study of comparative embryology, anatomy and histology of plants, the study of fossil plants found in the rocks of past ages of the world's history in comparison with living forms of the present age, the comparison of life histories of present day plants, and through the more recent sero-diagnostic tests of Carl Mez and his pupils.

A system of classification based upon natural resemblances of plants related by descent is called a **natural system.** Any system of classification which does not take into account the natural kinships and evolutionary tendencies existing between plants is called an **artificial system.**

A number of artificial systems were derived and used by botanists of the past. Most of them were based upon some arbitrarily chosen character such as woody stems, petals, stamens, etc.

Theophrastus (370–285 B.C.), a pupil of Aristotle, and probably the earliest of pioneers in attempting a scientific grouping of plants,

classified them structurally into trees, shrubs, undershrubs, and herbs. He was the first to distinguish between certain natural families.

Leonhard Fuchs (1501–1566), a German physician and botanist, chose to arrange plants alphabetically by their Greek names.

Gaspard Bauhin (1560–1624), a Swiss botanist, grouped plants into seaweeds, grasses, lilies, trees and shrubs.

FIG. 190.—Linnaeus, the father of modern systematic botany. (*After Gager.*)

John Ray (1627–1705), an English botanist, arranged plants into two chief divisions, viz.; woody plants and herbs and made cotyledons a basis for subdividing flowering herbs into *monocotyledons* and *dicotyledons*.

Joseph P. De Tournefort (1656–1708), an eminent French botanist, chose petals as his basis of grouping and subdivided the flowering plants into the *Apetali* or the plants without petals and the *Peta-*

lodes or those possessing petals, distinguishing herbs and undershrubs, trees and herbs. He was the first botanist to describe genera.

The greatest of these artificial systems was that of the Sexual System of Carl von Linné, popularly called Linnaeus (1707–1778), a Swedish naturalist, who through his great works, *Systema Naturæ*, published in 1735 and *Species Plantarum*, published in 1753, did more to establish Botany on a scientific foundation than any previous investigator. Linnaeus divided plants into sexual and asexual, the former of which he designated as *Phanerogamia* or flowering plants and the latter as *Cryptogamia* or flowerless plants. His classification of the flowering or seed plants was based primarily on the number and position of the stamens, each of the larger groups being subdivided according to the number and character of the carpels. In his *Species Plantarum*, he systematically described a great list of plants giving to each species a binomial name consisting of two Latin words. This system of naming plants, called the **"binomial system,"** has been followed by all scientific botanists since Linnaeus and is still in use at the present day.

The first natural system of classification was that devised by Antoine Laurent de Jussieu, a French botanist, who in 1789, issued his *Genera Plantarum*. This work formed the basis of all future natural systems. Jussieu was the first to group the genera into families, and many of his concepts on families are used with modifications to-day.

In 1813, Augustin P. De Candolle, a follower of the teachings of Jussieu, issued his *Theorie elementaire de la botanique* in which he demonstrated that the affinities of plants are to be found through the study of the comparative embryology and structure of plant organs. He later published his famous *Prodromus* which was continued by his son Alphonse de Candolle with the aid of eminent collaborators. This work gives descriptions of genera and species of Dicotyledons and represents a modification and elaboration on the system of Jussieu.

From 1862 to 1883, George Bentham and Joseph D. Hooker, two eminent British botanists, issued their *Genera Plantarum*. This work contains a systematic arrangement of the Phanerogams with a description of all of the genera then known.

This system was followed by the systems of A. W. Eichler (Berlin 1883) and of Engler and Prantl. The latter, called "*Die naturlichen Pflanzenfamilien*," has since its appearance become the most popular guide of systematists. It is based on the belief that the absence of a perianth is a primitive condition and that Monocotyledons precede Dicotyledons.

In 1926, J. Hutchinson, of the Royal Botanical Gardens at Kew, issued the first volume of his work, "*The Families of Flowering Plants*." This is a new natural system on the seed plants and is based on the assumption that plants with sepals and petals associated with other floral and anatomical characters regarded as primitive are more ancient than plants without sepals or petals. The Monocotyledons are placed after the Dicotyledons from which they are claimed to have been derived.

In every modern natural system, every individual belongs to a species or unit of classification.

A **species** is a mental concept of a group of individual plants having certain essential characters in common. Thus, all the Oak trees which we commonly recognize as white oak constitute the species *Quercus alba.*

Moreover, every species belongs to a genus, every genus to a family, every family to an order or cohort, every order to a class, every class to a subdivision and every subdivision to a division or phylum of the Plant Kingdom.

A **genus** is a group of related species. Thus, the plants we recognize as red oak, scarlet oak, pin oak and white oak belong to the genus **Quercus.** The chief structure upon which the concept of a genus is based is the flower, but other organs also play a part.

A **family** is a group of similar and related genera. Thus, the oak genus (*Quercus*), the chestnut genus (*Castanea*) and the beech genus (*Fagus*) constitute the family called *Fagaceæ.*

An **order** is a group of related families. Thus, the Beech Family *Betulaceæ*), the Hazel Family (*Corylaceæ*) and the Oak Family (*Fagaceæ*) constitute the order known as *Fagales.*

It will be noted that the common family ending is **aceæ,** more rarely **æ** and the order ending **ales.**

A **class** is a still higher group composed of related orders. Thus, the *Fagales*, *Ranales* and a large number of other orders are placed in the Class Dicotyledoneæ, because all of them have several outstanding characteristics in common, such as netted-veined leaves, two cotyledons in embryo, parts of their flowers in fours and fives, and open collateral bundles.

A **subdivision** is a group of related classes. Thus, the Class Dicotyledoneæ and the Class Monocotyledoneæ, while differing in several characters, resemble each other in possessing covered ovules and seeds and so are placed in the subdivision *Angiospermæ*. A **division** or **phylum** is composed of related subdivisions. Thus, the Subdivision Angiospermæ or related plants having covered seeds and the Subdivision Gymnospermæ or plants with naked seeds agree in possessing seeds and so are placed in the Division Spermatophyta.

The Divisions Spermatophyta (seed plants), Pteridophyta (ferns and their allies), Bryophyta (liverworts and mosses) and Thallophyta (seaweeds, fungi, etc.) make up the **Kingdom of Plants.**

In some instances species are subdivided into smaller groups called **varieties** and these in turn into **subvarieties, forms** and **strains.** Classes may be subdivided into **sub-classes.** Thus the Class Dicotyledoneæ contains two subclasses, the **Archichlamydeæ** or that group in which the petals are either distinct and separate or entirely wanting and the **Metachlamydeæ** or **Synpetalæ** in which the petals are more or less joined to form a tubular corolla. Large families may be subdivided into **sub-families** or tribes which in some works are given full family rank.

A **hybrid** is a cross breed of two varities or species, rarely of two genera.

A complete classification of the medicinal plant, Aconite, will show the principal subordinate groups of one of the divisions.

Division-Spermatophyta (seed plants).
Subdivision-Angiospermæ (seeds enclosed).
Class-Dicotyledoneæ (seeds with two cotyledons).
Sub-class-Archichlamydeæ (petals disjoined).
Order-Ranales (carpels disjoined, etc.).
Family-Ranunculaceæ (herbs with many hypogynous stamens).
Sub-family-Helleboreæ (petaloid sepals hooded).
Species-Aconitum Napellus (carpels, 3 or 4; etc.).

OUTLINE OF PLANT GROUPS

Thallophyta	Algæ	Cyanophyceæ	Blue-green algæ
		Chlorophyceæ	Green algæ
		Bacillarieæ	Diatoms
		Phaeophyceæ	Brown algæ
		Rhodophyceæ	Red algæ
	Fungi	Schizomycetes	Bacteria
		Myxomycetes	Slime molds
		Phycomycetes	Alga-like fungi
		Ascomycetes	Sac-fungi
		Basidiomycetes	Club fungi
		Deuteromycetes	Fungi imperfecti
	Lichens	Ascolichens	Lichens
		Basidiolichens	Lichens
Bryophyta	Hepaticæ	Ricciales	Riccia, etc.
		Marchantiales	Marchantia, etc.
		Jungermanniales	Leafy liverworts
		Anthocerotales	Anthoceros, etc.
	Musci	Andreæales	Black mosses
		Bryales	True mosses
		Sphagnales	Peat mosses
Pteridophyta	Lycopodineæ	Lycopodiales	Club mosses
		Selaginellales	Little club mosses
		Isoetales	Quillworts
	Equisetineæ	Equisetales	Horsetails
	Filicineæ	Ophioglossales	Adder's tongue ferns
		Filicales	Ferns
		Hydropterales	Water ferns
Spermatophyta	Gymnospermæ	Cycadales	Sago palms
		Ginkgoales	Ginkgos
		Coniferales	Conifers
		Gnetales	Gnetums and ephedras
	Angiospermæ	Monocotyledoneæ	Grasses, lilies, etc.
		Dicotyledoneæ	Willows, cherries, etc.

BOTANICAL NOMENCLATURE

Before Carl von Linné (Linnaeus), the great Swedish naturalist, brought forth the binomial system of nomenclature, no uniformity existed in the assignment of plant names. Among the pre-Linnean botanists there were some who designated plants by single names, others who employed sentences in naming them, some of which were quite lengthy, and a number who adhered to the practice of naming them in their own modern tongue. The result was quite obvious, a number of systems were employed and confusion prevailed among students.

According to the binomial system which has been universally adopted, every plant belongs to a species which is given two Latin names. The first name is the name of the genus or **generic name,** the second, the name of the species or **specific name.** The generic name corresponds, in the naming of persons, to the surname or family name, while the specific name is analagous to the given name. Thus, the Wild Cherry **species** is named *Prunus serotina*, *Prunus* representing the name of the genus, *serotina* the specific name or kind of *Prunus*.

Generic Name.—The name of the genus (pl. genera) is always a noun in the singular number and must not be applied to more than one genus. Its spelling should begin with a capital letter. Genera names may be taken from any source whatever. Some, like *Fagus* for the Beech genus, and *Acer* for the Maple, are of Latin origin. Others have been latinized from other languages. Some have been named after some therapeutic property, their roots, leaves, flowers or seeds were thought to possess; for example, *Jateorhiza*, a latinized compound of two greek words, ἰάτειρα, healing, + ῥιζα, root, because of the healing virtues of the root. A number have had names ascribed to them because of some peculiarity of structure, color, taste, odor, behavior, habit or appearance of the plant or portion thereof.

Thus, *Eriodiciyon* (from Gr. ἔριον, wool + δίκτυον, net) alludes to its wooly, netted veined leaves; *Melaleuca* (from Gr. μέλας, black, + λευκός, white) alludes to the black bark of the trunk and white bark of the branches; *Marrubium* (from Hebrew *marrob*, bitter) refers to its bitter sap; *Barosma* (from Gr. βαρύς, heavy + οσμή,

odor) in allusion to its strong smell; *Epiphegus* (from Gr. ἐπί, upon + φηγός, the beech) alludes to its growth on the roots of that tree; *Impatiens* (from Lat. *in*, not and *patiens*, enduring) refers to the sudden bursting of the capsules of this genus when touched; *Lycopodium* (from Gr. λύκος, a wolf, + πούς, a foot) pertains to the appearance of the shoots of this genus. Many have been named in honor of eminent naturalists or friends of these, or other noted persons. For example, *Collinsonia* was named in honor of Peter Collinson, an English botanist of the 18th century; *Dioscorea* in honor of Dioscorides, the Greek naturalist; *Paullinia* after Paullini, a German botanist of the 17th century; *Cinchona* in honor of the countess of Chinchon, who brought the bark to Europe in 1640 and *Jeffersonia*, in honor of Thomas Jefferson.

Specific Name.—The specific names are for the most part adjectives which agree with the names of genera to which they belong in case, gender, etc. They may, however, be nouns and in a few instances consist of two nouns or a noun and an adjective. If an adjective, it should begin with a small letter, as in *Rhus glabra* and *Evonymus atropurpureus*. When the specific name is a noun, it may either be a proper noun in the genitive case when it should begin with a capital, as *Garcinia Hanburyi;* or it may be a common noun in the genitive, when it should begin with a small letter, as *Grindelia camporum;* or the noun may be in apposition to the generic name and so in the same case, as *Cytisus scoparius*. Names that had formerly been used for genera but since reduced to species are usually capitalized, whether originally proper nouns or not, as *Aristolochia Serpentaria* and *Anacyclus Pyrethrum*. In cases where two nouns make up the specific name, the first of these is in the nominative case, the second in the genitive, the two names being connected by a hyphen, as *Capsella bursa-pastoris*. The botanical name of the species yielding the drug, Aspidosperma, (*Aspidosperma Quebracho-blanco*) will serve as an example of the specific portion of the names being composed of a noun and an adjective. Specific names taken from names of persons begin with a capital.[1]

[1] There is a growing tendency amongst botanists to use the small letter in beginning the spelling of all specific names irrespective of their source. This plan has been adopted in the compilation of the "Official Catalogue of Standardized Plant Names" by the American Joint Committee on Horticultural Nomenclature.

Variety Name.—Names of varieties are applied in three different ways. Either the name of the species is given and followed by the prefix var. before the varietal name, as *Chenopodium ambrosioides* var. *anthelminticum;* or the varietal name may be appended to the name of the species, as *Chenopodium ambrosioides anthelminticum;* or the varietal name may be placed immediately after the name of the genus and the specific name dropped, as *Chenopodium anthelminticum.*

It frequently happens that a botanist is careless in naming a species and, without ascertaining whether the same name has been assigned to another species, applies it to his, thus causing duplication. For example, there are two distinct species of plants named *Prunus virginiana*, one of these, the Wild Black Cherry, the other, the Choke Cherry. In this instance the name *Prunus virginiana* does not tell us which species the writer or speaker refers to. It might be the Choke Cherry named "*Prunus virginiana*" by Linnaeus or the Wild Black Cherry named "*Prunus virginiana*" by Miller at a later date. Accordingly, it is necessary to add to the name of the species the author's name. Thus, *Prunus virginiana* Linné refers to the Choke Cherry while *Prunus virginiana* Miller refers to the Wild Black Cherry. In this connection it is customary to abbreviate the name of the author thus, L. for Linné, Mill. for Miller, Ait. for Aiton, Loisel. for Loiseleur-Deslongchamps, or Tourn. for Tournefort.

Whenever a plant is transferred from one genus to another, it must retain its original specific name, unless the genus to which it is transferred already possesses a species with that name, in which case a new specific name must be given it. Moreover, the name of the botanist who assigned the original specific name but placed it under a different genus must be placed in parenthesis between the specific name and the name of the botanist who later connects it with another genus. For example, we read as the official definition for Purging Cassia in the National Formulary V—"The dried fruit of *Cathartocarpus Fistula* (Linné) Persoon." The significance of the name Linné in parenthesis is that he had previously given the specific name *Fistula* to the plant indicated but placed it under a different genus, which genus happened to be *Cassia.* Therefore, Persoon, in connecting it up with another genus *Carthartocarpus,* avoided

binomial duplication by interjecting Linné parenthetically between his name and the specific name, *Fistula*.

Family Name.—The names of families are designated by the name of one of their principal genera or ancient generic names with the ending aceæ, *e.g.*, *Ranunculaceæ* from *Ranunculus*, *Malvaceæ* from *Malva*, etc. The following names, because of long usage, are exceptions to the rule: *Palmæ*, *Gramineæ*, *Guttiferæ*, *Umbelliferæ*, *Labiatæ*, and *Compositæ*.

Order Name.—Orders are generally designated by the name of one of their principal families, with the ending ales, *e.g.*, *Rhamnales* from *Rhamnaceæ*, *Rosales* from *Rosaceæ*. Suborders are likewise designated, but with the ending—ineae, *e.g.*, *Malvineæ* from *Malvaceæ*. Other older endings may, however, be retained for these names providing they do not lead to confusion or error.

Class Name.—Names of classes, subclasses, divisions and subdivisions are designated from one of their characters by words of Latin or Greek origin, some similarity of form and ending being given to those that designate groups of the same nature, as Monocotyledoneæ, Dicotyledoneæ; Archichlamydeæ, Metachlamydeæ; Thallophyta, Spermatophyta; Gymnospermæ; Angiospermæ.

In the case of Cryptogams, the use of old family names as Algæ, Fungi, Lichens, Musci, etc. is permissible for designating groups above the rank of family.

For further details on botanical nomenclature, the student is referred to the following articles:

International rules of nomenclature adopted by the International Botanical Congress of Vienna. Rhodora, March, 1907.

The American code Bul. Torrey Bot. Club, **31**: 249, 1904 and **34**: 167, 1907.

Recommendations of the committee on nomenclature of the Botanical Society of America. Science, **49**: 333–336, 1919 and **53**: 312–314, 1921.

CHAPTER XVII

THE ALGÆ

The algæ (*sing.* alga) are forms of thallophytes found on land and in fresh, brackish or salt water. They consist for the most part of single cells or rows of single cells joined end to end to form filaments. The higher forms, however, possess structures which, while appearing like stems and leaves of higher plants, are merely sheets or cylinders of many celled filaments, closely arranged and connected by protoplasmic connections. They contain chlorophyll, and so can use the CO_2 and H_2O in the same manner as higher plants, *e.g.*, in building up food and providing for their own nutrition. In addition to chlorophyll, some contain one or more additional pigments. Archegonia are absent in this group.

Class I.—Cyanophyceæ, the Blue-green Algæ

Plants which are sometimes termed *blue-green algæ*. They contain chlorophyll, a green pigment, and *phycocyanin*, a blue pigment, a combination giving a blue-green aspect to the plants of this group. Found everywhere in fresh and salt water and also on damp logs, rocks, bark of trees, stone walls, etc. Examples: *Oscillatoria*, *Glœocapsa*, and *Nostoc*.

Glœocapsa.—This blue-green alga is commonly found on old, damp flower pots in greenhouses and on damp rocks and walls near springs, where it forms slimy masses. Under the microscope a mount of Glœocapsa will be seen to consist of isolated protoplasts and groups of protoplasts, surrounded by concentric gelatinous envelopes. Each protoplast consists of a protoplasmic mass which contains blue and green pigments. No definitely organized nucleus is apparent but chromatin in the form of granules is scattered through the protoplasm. The whole is surrounded by a cell wall which undergoes mucilaginous modification producing thus

the soft gelatinous envelopes which encircle parent-, daughter-, grand-daughter- and even great-grand-daughter-cells.

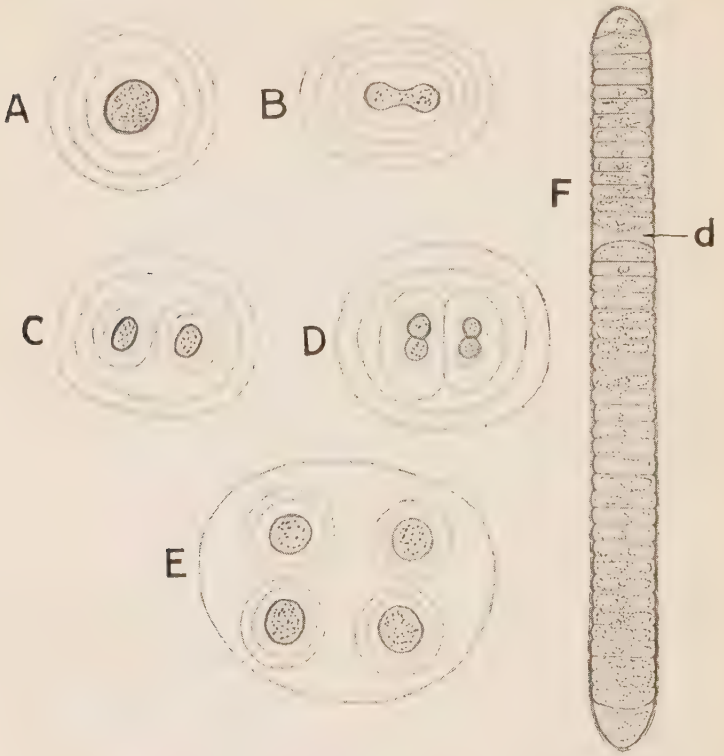

FIG. 191.—*A*, *B*, *C*, *D*, *E*, *Glœocapsa*; *F*, *Oscillatoria* showing a dead cell (*d*) which marks a place of separation into segments. (*A*), *Glœocapsa*, parent cell composed of central protoplast containing scattered chromatin granules, surrounded by cell wall and 3 mucilaginous envelopes; (*B*), parent cell is shown elongated, the protoplast in process of division to form two daughter protoplasts; (*C*), daughter protoplasts, each surrounded by two gelatinous envelopes and both within the original parent envelopes; (*D*) the daughter protoplasts shown in *C* have just divided to form granddaughter protoplasts which have later separated, each forming envelopes of its own but all four encircled by the parent envelope.

Oscillatoria.—Oscillatoria is a blue-green, filamentous organism found abundantly on the surface of the mud of drains and ditches as well as in ponds where the water is foul. The filament is slender and composed of compactly arranged disc-shaped cells which are

all alike, excepting the terminal ones which appear rounded off. The filaments tend to be agglomerated in thick felts or gelatinous masses and each possesses peculiar oscillating and forward movements. At the time of reproduction the filament breaks up transversely into short segments, each of which, by fission occurring among its cells, grows into a new filament.

Nostoc.—Nostoc occurs on the damp ground bordering streams or in slow bodies of water as greenish or brownish, tough, gelatinous masses varying in size from a pea to a hen's egg. When one of these masses is dissected and examined microscopically, it is seen to contain, imbedded in a gelatinous matrix, numerous serpentine filaments, composed of spherical or elliptical cells loosely attached to each other in chain-like fashion. Most of the cells are of the blue-green vegetative kind, but there occur at intervals larger cells, often devoid of protoplasm which are termed *heterocysts*. Frequently the filaments break apart on either side of the heterocyst, setting free segments of cells which grow into new filaments.

FIG. 192.—*Nostoc.* (*h*), a heretocyst.

CLASS II.—CHLOROPHYCEÆ, THE GREEN ALGÆ

Green algæ are unicellular (sometimes motile), filamentous, colonial, or sheet-like water plants characterized by the presence of solitary, or numerous chloroplasts in the cells which compose the thallus. These chloroplasts vary considerably in form, being in some cases spiral bands, in others star-shaped, in others like a napkin ring, and in others granular. In the chloroplasts of most green algæ are *pyrenoids*, which consist of a central crystalline por-

tion of protein (aleurone-like) surrounded by a starchy envelope of variable magnitude. These are called starch centers and the starch is frequently in the form of rounded, or angular grains. The nutrition of these algæ is autotrophic. There is a definite nucleus present, but in the coenocytic forms the nuclei may be many within the confines of the cell wall. The motile cells have two (except in *Oedogoniaceæ* and by fusion in the *Vaucheriaceæ*) to many cilia, as likewise some of the reproductive cells. No cilia occur in the conjugate algæ. Reproduction is by cell division, the formation of zoöspores (motile cells), by zygospores produced by conjugation, by egg cell and sperm cell union (oospores) oogamous reproduction. Green algæ live mostly in fresh water. Some live in sea water and a few in brackish water. Some are associated with fungi to form lichens.

1. **Order Protococales or One-celled Green Algæ.**—This order contains nearly all of the one-celled green algæ excepting the diatoms and desmids.

Family Pleurococcaceæ.—*Pleurococcus vulgaris* [Fig. 193 (2)] is a one-celled green alga, millions of which, living together in colonial fashion, constitute the so-called "green stain" that is common on the north sides of tree trunks, stone walls and fences. Each organism consists of a protoplast surrounded by a cell wall of cellulose. The protoplast contains a chromatophore (capable of division into 2 or more chromatophores), cytoplasm and nucleus. Reproduction takes place by the protoplast dividing into two equal parts and laying down a cell wall forming two daughter-protoplasts. These may again divide to form four granddaughter-protoplasts. Still another division may occur as a result of which eight great-granddaughter-protoplasts are formed which frequently adhere to one another forming colonies.

2. **Order Volvocales.**—This order comprises free-swimming aquatic forms whose vegetative cells are bi-ciliated, green, more or less spherical or compressed. Some of the organisms like *Sphærella* [Fig. 193 (3)] and *Chlamydomonas* consist of single cells bearing a pair of cilia, while others like *Pandorina*, *Eudorina* and *Volvox* show varying degrees of colony formation. Reproduction sexual or asexual.

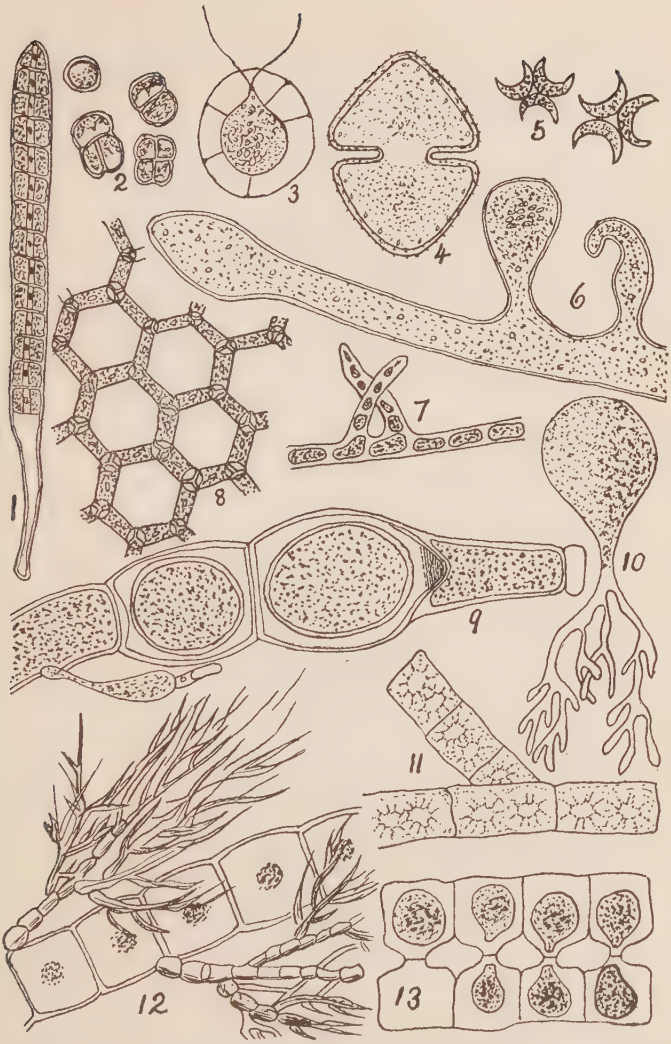

FIG. 193.—Various types of Green Algæ. *Ulothrix* (1); *Pleurococcus* (2); *Sphærella* (3); *Cosmarium* (4); *Rhaphidium* (5); *Vaucheria* (6); *Rhizoclonium* (7); *Hydrodictyon* (8); *Oedogonium* (9); *Botrydium* (10); *Zygnema* (11); *Draparnaldia* (12); *Zygnema* during conjugation (13).

Volvox globator, a typical representative of this order, is found in fresh water pools as a tiny, hollow, spherical, green colony about $\frac{1}{50}$ to $\frac{1}{30}$ of an inch in diameter. When examined under the microscope (Fig. 194), it is found to consist of hundreds of green, more or less spherical cells, united by fine strands of cytoplasm (protoplasmic bridges), the whole being enveloped by a gelatinous sheath. The peripheral cells are provided with cilia, in order that the colony may rotate and roll through the water. In a young colony, all of the cells are alike, each consisting of a mucilaginous-like cell-wall enclosing cytoplasm, a nucleus, a chloroplast and often a red pigment spot. In a mature colony, however, throughout the greater part of its existence, two kinds of cells may be discerned: small, sterile, vegetative cells that do not divide and from 10 to 12 larger vegetative ones that divide to form new colonies. The latter slip inward below the level of the smaller cells and through repeated divisions form a number of ciliated cells joined by cytoplasmic threads, which in reality is a minature colony. This then escapes to the exterior through the rupturing of the gelatinous wall of the old colony.

During autumn of the year, certain of the ordinary cells undergo differentiation, some to form sperm cells, others, egg-cells. When about three times the size of the ordinary sterile cells, the sperm cells divide repeatedly to form a cluster of elongated secondary cells [Fig. 194 (1*a*, a^2 and 5)] each of which contains an orange colored pigment with a red corpuscle and an elongated beak, bearing a pair of *flagella* (lash-like processes). The cluster in time separates into motile *antherozoids* [Fig. 194 (6, 7)] which finally escape into the cavity of the volvox sphere through rupture of the investing wall. The flask-shaped *egg cells* (1*b*, *b*) increase greatly in size without dividing. Each shows vacuoles, then becomes filled with a dark green pigment, becomes spherical and acquires a gelatinous envelope. It then passes into the cavity of the sphere where it is surrounded by numerous antherozoids (3) and is finally fertilized.

The product of this fertilization is an *oöspore* (4) which ere long becomes covered with an internal smooth membrane and a thicker external spinose coat. The chlorophyll within then disappears and starch and a reddish- or orange-colored oil make their

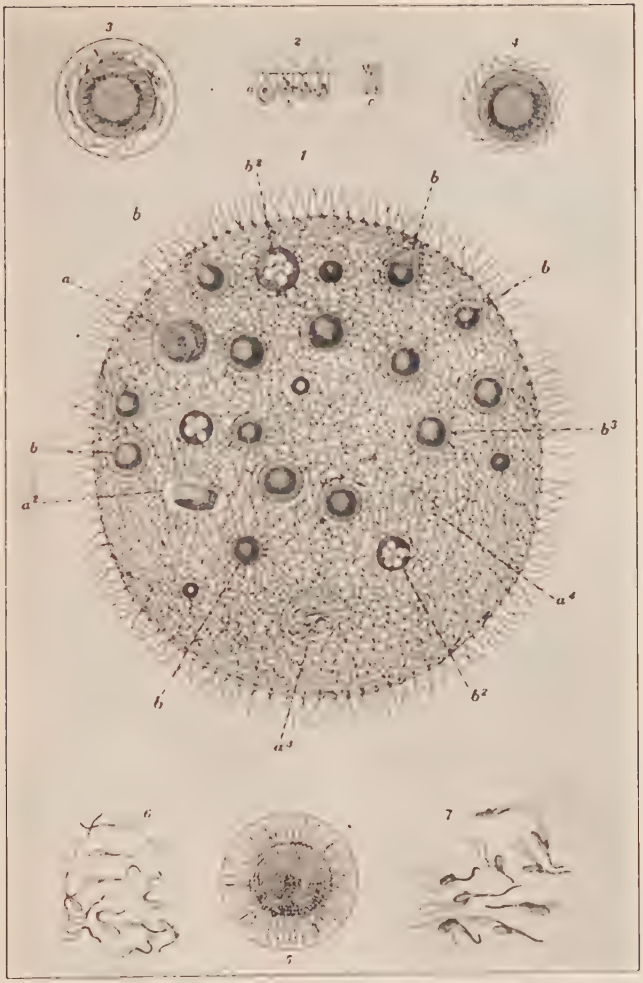

FIG. 194.—*Volvox globator.* Mature colony in center (1); sexual cells (2*a*); endochrome of primary cell has resolved itself into a cluster of secondary cells (1*a*, a^2 and 5); antherozoids (6, 7); bundle separated into component antherozoids in cavity of primary cell (1a^3); breaking of wall of primary cell showing escape of antherozoids into cavity of volvox sphere (1a^4); egg cells (1*b*, *b*); flask shaped germ (egg) cells with large vacuoles in protoplasm (1b^2, b^2); globular egg cells prepared to pass into cavity of volvox sphere (b^3); antherozoids collected about egg cell (3); oöspore (4). (*Carpenter.*)

appearance. Up to 40 of these oöspores have been observed in a single volvox sphere. Not long after the formation of these oöspores the whole parent colony breaks up and the oöspores fall to the bottom of the pool to pass the winter season. As early as February each oöspore germinates to form another volvox colony, which repeats the life cycle described.

3. **Order Confervales.**—In this order are included a variety of green filamentous and membranous forms some of which show sexual reproduction.

Family Ulothricaceæ.—*Ulothrix zonata*, [Fig. 193 (1)] a typical representative of this family, is a filamentous organism found grow-

FIG. 195.—*Vaucheria terrestris*, a siphon alga. *anth*, antheridium (empty); *o*, oögonia. (*Gager.*)

ing on stones around ponds, on rocks along the shores of lakes, in slow-moving streams, etc. Each filament is unbranched and consists of a row of short cells; one of the terminal cells, called the *rhizoid cell* is elongated and serves as an attachment structure. Each cell consists of a cell wall of cellulose enclosing cytoplasm, a nucleus and a wide, band-shaped, green chromatophore, more or less cylindrical in shape. The *chromatophore* (chloroplast) lies next to the cell wall and contains *pyrenoids* or starch-forming centers. The filament grows in length by the fission of its various component cells. After attaining a certain size it reproduces either asexually or sexually. Asexual reproduction takes place by certain cells becoming altered in their protoplasmic contents, through division, to form rounded or pear-shaped *zoöspores*. Each zoöspore contains

a red pigment spot and bears four cilia (protoplasmic outgrowths). The zoöspores escape into the water by lateral openings in the walls of cells containing them. They swim rapidly about, propelled by their cilia, and ere long attach themselves to various objects and grow into Ulothrix filaments. The sexual method of reproduction is effected through the production of many *gametes*, in cells of the filament. These resemble the zoöspores in shape but differ from them in being smaller and possessing but two cilia. These escape into the water and, after swimming about for a short time come together in pairs and fuse with one another. The product of the fusion of each pair of these like gametes is termed a *zygospore*. The zygospore swims about but finally comes to rest, remaining quiescent for a considerable length of time. It then enlarges and its protoplasmic content divides to form several zoöspores which, escaping from the cell, swim about for a while and finally, attaching themselves to objects, grow into filamentous *Ulothrix* organisms.

4. **Order Conjugales.**—To this order belong the desmids and pond scums which are distinguished from other green algæ by presenting no motile stages in their life histories. They are all of fresh-water habit and reproduce by conjugation.

Family Desmidaceæ.—The desmid family includes a number of genera of unicellular as well as filamentous green plants that present a variety of shapes. Each unicellular desmid [see Figs. 193 (4, 5)] is characterized by being composed of two like halves frequently separated from each other by a constriction called the *isthmus*. In each half there is a *chromatophore* containing *pyrenoids*. The *nucleus* is found in the isthmus. Reproduction is accomplished either asexually by fission or sexually by conjugation.

Family Zygnemaceæ.—This is a family of pond scums including the well-known genera, *Spirogyra* and *Zygnema* [Fig. 193 (11, 13)].

Spirogyra or *Brooksilk* is a filamentous organism found suspended or floating in masses in quiet water. Each filament, when examined microscopically, will be found to consist of more or less elongated cylindrical cells arranged end to end, the terminal cells having rounded extremities. Each cell has a cell wall of cellulose within which is to be found a thin film of *ectoplasm*. One or more spirally shaped *chromatophores* will be seen directly within this area. Each

chromatophore contains *chlorophyll* and a number of *pyrenoids*. In the center of the cell the *nucleus* is found. Fine strands of protoplasm hold it in place and run out to the ectoplasm.

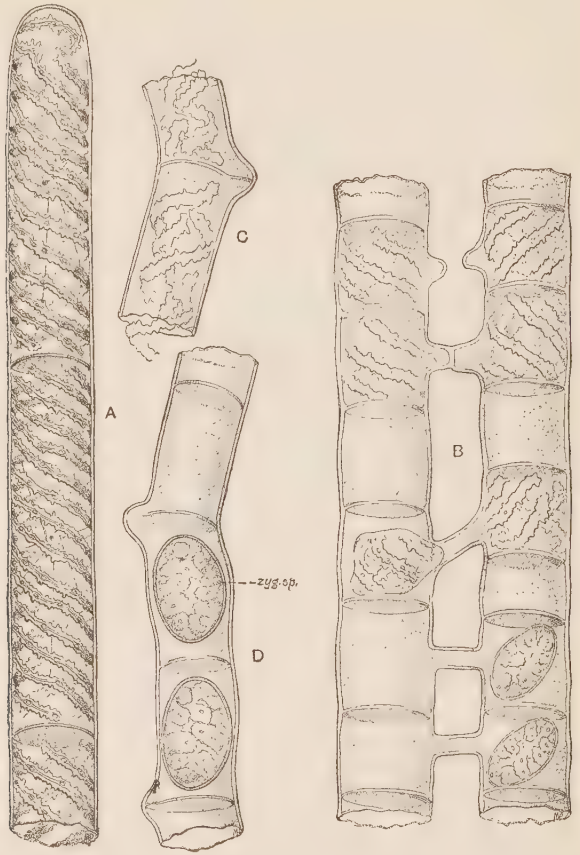

FIG. 196.—*Spirogyra* sp. *A*, terminal portion of vegetative filament; *B*, stages of scalariform conjugation; *C*, preparation for lateral conjugation; *D*, zygospores formed by lateral conjugation. (*Gager.*)

Under favorable circumstances the cells of *Spirogyra* increase rather rapidly in length. Abnormally long cells are not seen, however, because the elongating cells speedily divide, forming two

daughter-cells. Under the best of conditions, division may occur every night. In this way the filaments are rapidly made longer. Sooner or later they break and in this way the plant multiplies.

Spirogyra has also a process of sexual reproduction known as conjugation. This process occurs normally from March to June and July, but can be induced in the laboratory by allowing the water in the vessel in which it is growing to slowly evaporate. Two filaments arrange themselves side by side, and the cells lying opposite each other undergo internal changes so as to form *gametes* or sexual cells. Each gamete protrudes a process or lateral branch. The

FIG. 197.—*Spirogyra longata*. Portion of a monoecious filament showing two adjacent cells in the early stages of conjugation. This type of conjugation is called *lateral*. Ladder-like or *scalariform* conjugation of dioecious filaments is shown in figure 196. Note the pulsating or contractile vacuoles. (*From Gager, after Lloyd.*)

tips of these fuse upon meeting each other and form a conjugation or connecting tube. Then the protoplast of one cell passes over and coalesces with that in the cell opposite. The result of the process is a new cell called a *zygospore* or *zygote*. The zygospore forms a thick cell wall about itself. It is set free by decay of the walls of the old cell and falls to the bottom of the water, there to undergo a resting stage until favorable conditions for growth arise.

Professor F. E. Lloyd has recently shown that in *Spirogyra longata*, conjugation takes place between adjacent cells of the same filament. In this case a protrusion of the cell wall of the filament occurs opposite the partition wall of adjacent gametes, forming a

channel of communication between the gametes. Pulsating or contractile vacuoles, such as have been described in Amœba appear in the protoplast and upon contraction propel the gamete in one

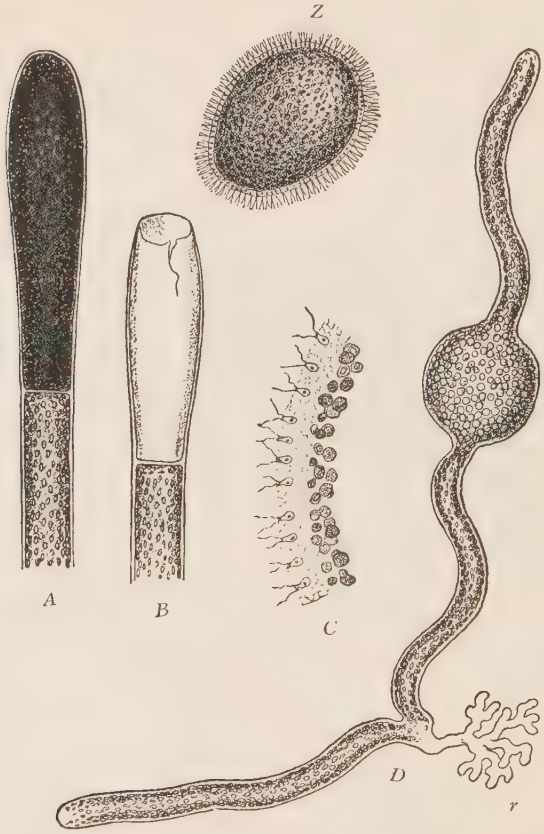

FIG. 198.—*Vaucheria sessilis*. *A*, Terminal portion of a filament showing the appearance of a partition wall separating the newly formed sporangium from the rest of the filament. *B*, Same, after escape of zoöspore (*Z*). *C*, A portion of the margin of the zoöspore. *D*, Young plant developed from a zoöspore with rhizoids (*r*). (*From Strasburger, Noll, Schenk and Schimper; A, B, Z, after Götz; D, after Sachs from Altmann's Algæ; C, after Strasburger.*)

cell cavity (*supplying gamete*) over into the cell cavity of the other gamete (*receiving gamete*). The fusion of these gametes results in the formation of a *zygospore*.

5. **Order Siphonales** (*Siphon Algæ*).—This group is characterized by the peculiarity that the organisms constituting it possess protoplasm containing myriads of nuclei within a common filament or cell cavity not segmented by cell walls. The term *cœnocyte* has been given to such structures which consist of a many-nucleated mass of protoplasm surrounded by a cell wall. Some of the siphon algæ reproduce by zoöspore formation, others by conjugation as well as zoöspore formation while *Vaucheria*, the green felt, stands out alone in reproducing both by the formation of a single zoöspore and

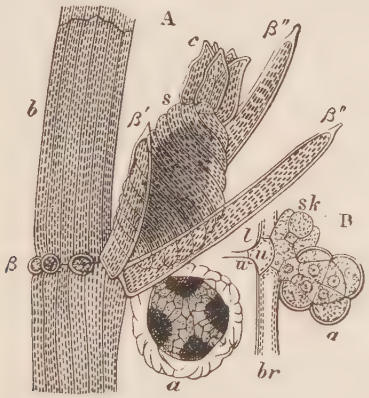

FIG. 199.—*A*. Portion of the axis of *Chara fragilis*, a stonewort. *s*. Oogonium (one-celled female sexual organ). *a*. Antheridium. *b*. Internode. *B*. Abortive "leaves." *B′*, *B″*. Sterile "leaves." *c*. Crown of oogonium. *B*. Young stage of the same. *br*. Cortical cell. *a*. Antheridium. *sk*. Oogonium. (*From Small, after Sachs.*)

by the production also of *oögonia* and *antheridia* with resultant fertilization (see Figs. 193 (6) and 195).

6. **Order Charales** (*The Stoneworts*).—**Family Characeæ.**—The highest group of algæ, possessing forms which are differentiated into stems, leaves and rhizoids.

Chara, a type of this family, is a submerged fresh-water plant which fastens itself to the muddy bottom of ponds, ditches and slow streams by means of slender filaments called rhizoids. From these there arises a many noded (jointed) stem which bears whorls of slender green leaves at its nodes. Branches are also found issuing

from some of the nodes which duplicate in appearance the main stem. Reproduction is either asexual or sexual. Asexual reproduction is accomplished by means of tuber-like bodies borne on submerged parts or by special branches which form *rhizoids* on their lower nodes and later become separated from the parent plant. Sexual reproduction is effected through the formation of *oögonia* (female sex organs) and *antheridia* (male sex organs). These in some species are borne on the same plant; in others, on different plants. In all cases the sexual organs are produced at the nodes. The oögonium develops within itself a large *ovum* or egg. The antheridium produces within its wall numerous motile sperms. Upon the maturation of the antheridium the sperms are liberated into the water, and, propelled by their cilia, find their way to the oögonia which they enter, the one best adapted fusing with the egg in each case and fertilizing it. The resultant cell is called the *oöspore*. This undergoes a resting stage and later germinates as a *proembryo*. The proembryo consists of a simple filament and a long rhizoidal cell. From this proembryo, the adult stem arises as a side branch.

Class III.—Bacillarieæ or Diatoms

This class comprises several thousand species of unicellular plants called *Diatoms* which are found in fresh, brackish and salt water, forming much of the diet of small animals. While unicellular, they frequently are united in colonies. They all possess chromatophores containing chlorophyll but this green pigment is often obscured by the presence also of a brown pigment.

The most striking peculiarity of the group is the structure of the enclosing cell wall. This is in the form of a siliceous case consisting of two *valves* which fit into each other like the halves of a pill box. The valves, which are beautifully sculptured with intricate patterns of lacework or of beading, are similar except that one is slightly larger than the other so as to fit over it. Diatoms vary in form, being either circular, linear, elliptical, cylindrical, rhomboidal, triangular, stellate, wedge-shaped, or fan-shaped, etc. Some are borne on the ends of stalks, while others are held in gelatinous masses. Their

siliceous skeleta are deposited constantly on the floor of ponds, rivers, lakes and seas, often in such abundance as to form Diatomaceous earths or Kieselguhrs (Siliceous Earths). Huge geological deposits of this material have been found in various parts of the world. One of the most remarkable for extent as well as for the number and beauty of the species contained in it is that at Richmond, Virginia. It is in many places 25 to 40 feet in depth and extends for many miles. Another deposit at Lompoo, California, is claimed to cover

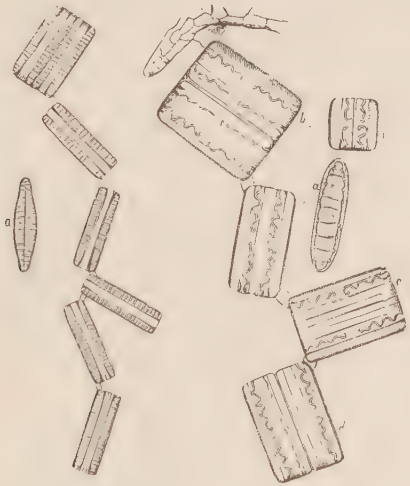

FIG. 200.—Two species of Diatoms. To left, *Diatoma vulgare*, *a*, side view of frustule; *b*, frustule undergoing division. To right, *Grammatophora serpentina*: *a*, front and side views of single frustule; *b*, *b*, front and end views of divided frustule; *c*, frustule about to undergo division; *d*, frustule completely divided. (*After Carpenter.*)

an area of 12 square miles with an average depth of over 100 feet. Many of the diatomaceous earths are useful as absorbent and polishing powders. *Terra Silicea Purificata* (Purified Siliceous Earth) is a powder consisting of the frustules and fragments of diatoms which has been purified by boiling with diluted hydrochloric acid, washed and calcined.

Diatoms exhibit two modes of reproduction, viz., fission and formation of an *auxospore*. The more common method is that of fission but this is peculiar for these plants. The cell-contents within

the siliceous case separate into two distinct masses and the valves separate slightly from each other. As the two daughter-masses become more and more developed, the valves of the parent-cell are pushed more widely apart. Each of the two masses secretes for itself a new valve on the side opposite to the original valve. When the process is completed the girdle of the parent-diatom separates

FIG. 201.—*Licmophora flabellata*, a diatom with wedge-shaped frustules borne on the ends of stalks, producing a fan-like arrangement. (*After Carpenter.*)

and the two daughter-diatoms thus become independent plants. Each of these possesses one of the parent valves and a second, which it has formed itself, more or less parallel to the first.

In a number of species, repeated fission results in the formation of succeedingly smaller and weaker individuals. This process, however, goes on only for a certain number of generations until the decrease of size has reached a limit for the species, when the plant is rejuvenated by the formation of an *auxospore*. This may be formed with or without the conjugation of two parent-protoplasts. In either case the auxospore resulting undergoes a resting stage after

which it develops new valves. The newly formed diatom is then several times the size of the individual or individuals which contributed to its formation and is endowed with renewed vigor for growth and division.

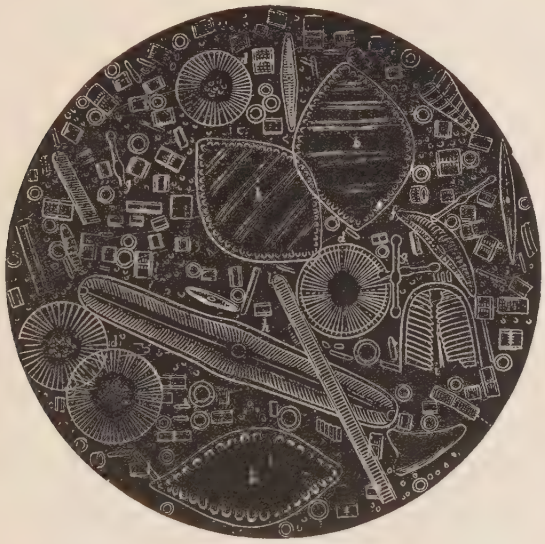

FIG. 202.—Fossil diatoms: *a, a, a, Gaillonella procera* and *G. granulata; b, b, Surirella plicata; c, Surirella craticula; d, d, d, Gaillonella (Melosira) biseriata* (side view); *e, Gomphonema gracile: f, Cocconema fusidium; g, Tabellaria vulgaris; h, Pinnularia dactylus; i, Pinnularia nobilis; k, Surirella caledonica; l, Synedra ulna.* (*After Carpenter.*)

CLASS IV.—PHAEOPHYCEÆ, THE BROWN ALGÆ

Mostly marine forms showing great diversity in the form of their vegetative bodies. They occur for the most part in salt water between the high and low tide marks. Their bodies are usually fixed to some support in the water by means of a holdfast, and are often highly differentiated both as to form and tissues. Some reach a hundred feet or more in length as, for example, *Macrocystis*, a giant kelp, which grows in the Pacific Ocean off the coast of California. They all contain the brown pigment called *phycophœin* and the green pigment, *chlorophyll*, both of which are present in their

chromatophores. A yellowish pigment called *phycoxanthin* has also been isolated from some of the species. Many of the kelps and rockweeds belonging to this class have long been sources of iodine, potash and sodium.

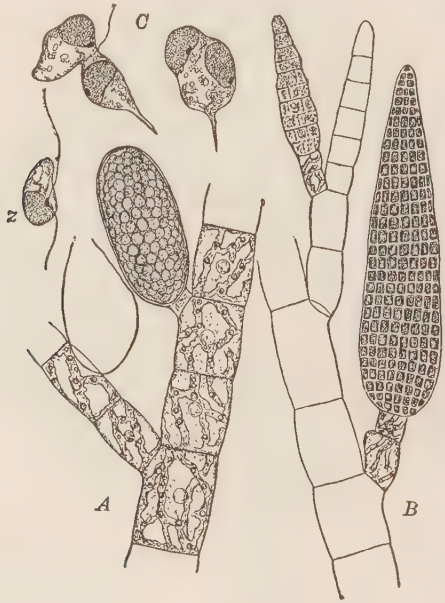

FIG. 203.—*Ectocarpus siliculosus*, a filamentous brown alga. *A*. Unicellular sporangia, one containing zoöspores, the other empty; *z*, a zoöspore. *B*. Plurilocular sporangia, the larger mature, the smaller still showing the outlines of the original cells in the branch from which it arose. *C*, Union of two gametes to form the zygospore.—*C*, after Oltmanns. (*From Bergen and Davis Principles of Botany.*)

A Filamentous Brown Alga, Ectocarpus Siliculosus.—*Ectocarpus* occurs as tufts of branching filaments, each of which is many-celled. These tufts are found on eelgrass or other algæ as well as attached to pilings of wharves in salt water. It is a striking illustration of the simplest form of brown algæ and serves to show the beginning of a more complex form of reproduction than that observed in the forms studied up to this time. On examination of a

filament we find it to consist of many cells joined end to end. A single cell has a cell wall of cellulose. Just within the cell wall there is a layer of protoplasm. Going toward the center we find an irregular chromatophore containing a brown pigment called *phycohæpin*. From certain cells of the filament spherical to elliptical *sporangia* (spore cases) arise, which are unicellular. They contain numerous biciliate *zosopöres*, which escape into the sea water, move

FIG. 204.—A giant Kelp, one of the Brown Algæ. (*From U.S.D.A. Bur. Soils.*)

about and later develop into new Ectocarpus plants. Along the filaments several branches will be seen. Some of these have undergone division into several cells and these again into still smaller cells until many-celled chambers have resulted, which are called *plurilocular sporangia*. Each cell of a plurilocular sporangium contains a *gamete* or sexual cell, which resembles in many details a zoöspore. When the sporangium matures these gametes are discharged into the

salt water. They fuse together in pairs and form *zygospores*. Each zygospore undergoes a resting stage and upon the advent of favorable conditions develops into a new *Ectocarpus* filament.

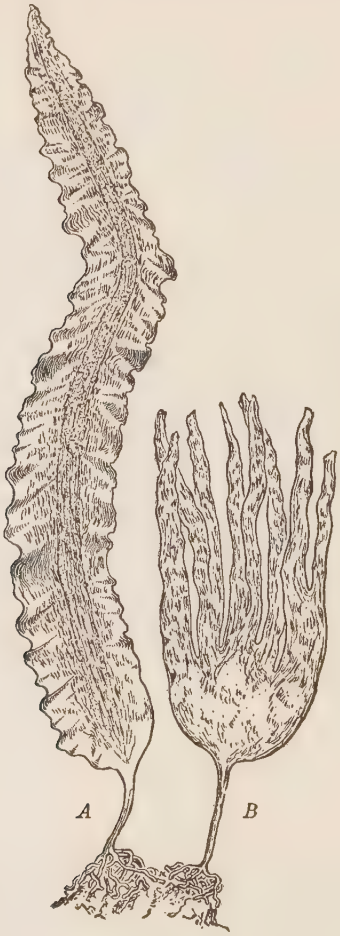

FIG. 205.—Kelps from the North Atlantic. *A*, The simple type of *Laminaria*, some of whose species grow to be thirty or more feet long. *B*, The digitate type (*Laminaria digitata*) which is never very long, but is broad at the base. (*From Bergen and Davis Principles of Botany.*)

The Kelps.—To this group (Order *Laminariales*) belong the largest living representatives of the Algæ. They are represented by the Devil's Aprons or *Laminaria* and the Sea Palms (*Postelsia*) which grow on rocks along the North Atlantic coast and by the

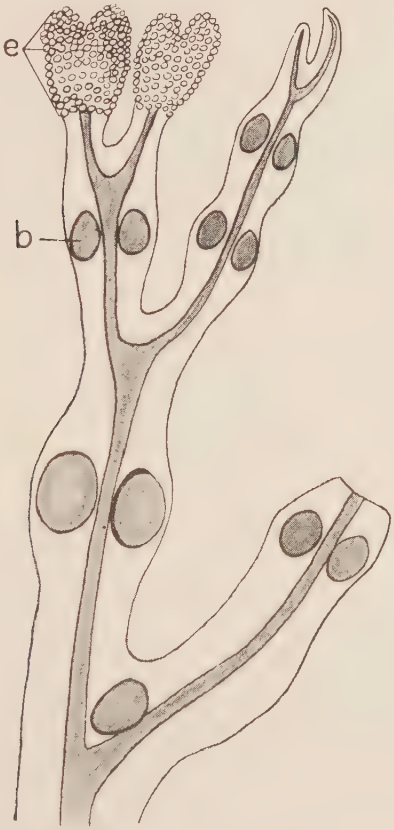

FIG. 206.—End of large branch of *Fucus vesiculosus*, a rockweed (natural size); *e*, receptacle; *b*, air bladder.

giant kelps *Macrocystis* and *Nereocystis* (Sea Otter's Cabbage) found along the Pacific coast of the United States.

Laminaria digitata is an abundant kelp off the coast of New England where it grows attached to rocks by a holdfast consisting of a whorl

of rootlet-like structures. From this arises a solid cylindrical stipe bearing on its end an oval or lance-shaped blade, the latter becoming split into finger-like segments at its summit. *Postelsia* or the Sea Palm has a holdfast of several whorls of stubby rootlet-like structures and a rigid stipe about a foot in length, the latter terminating in a number of lanceolate blades.

Because of their rich content of potassium salts, the kelps are used extensively as fertilizer. They also contain a fair amount of iodine and represent one of the chief sources of this drug.

The Rockweeds.- To this group (Order *Fucales*) belong the brown seaweeds which cover many of the rocks along our North Atlantic shores and mussel beds of our inlets. They all possess floats or bladder-like structures containing carbon dioxide and oxygen which

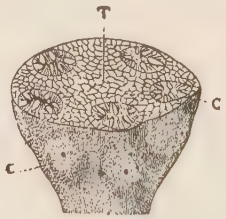

FIG. 207.—*Fucus vesiculosus.* Receptacle cut transversely. *c*, conceptacle, *T*, cellular thickness. (Magnified.) (*After Thuret.*)

aid in buoying up the plants in the salt water when submerged. Common forms occurring along the eastern coast of North America are *Fucus*, *Ascophyllum* and *Sargassum*. The last named is called the Gulf Weed because it is often found floating freely in the gulf stream. Large numbers of these plants often accumulate in quieter areas of the ocean where they form the so called "Sargasso Sea."

Fucus Vesiculosus (The Bladder Wrack).—This form, a brown alga, occurs as a flat thallus, which forks repeatedly, a type of branching called dichotomous. It grows near the surface of sea water, attached to rocks or to mussels along banks by means of a basal, *disc-shaped holdfast*. In the upper branches of the thallus are to be found *air-bladders* which are more or less spherical and usually in pairs. The tips of old branches become swollen and are termed *receptacles*. They are dotted over with minute warts, each having

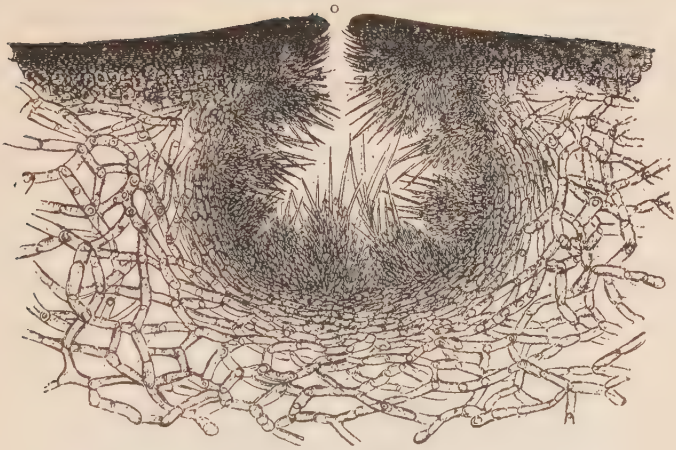

FIG. 208.—*Fucus vesiculosus.* Section of a male conceptacle lined with branched paraphyses which bear the antheridia; *o*, osteole through which sperms from mature antheridia escape. (Highly magnified.) (*After Thuret.*)

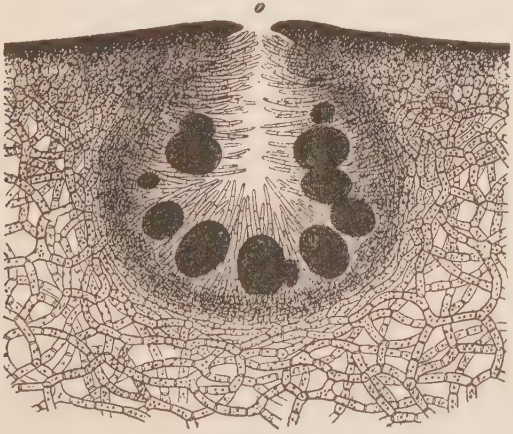

FIG. 209.—*Fucus vesiculosus.* Section of a female conceptacle. *o*, osteole by which the eggs escape. The oval shaped dark objects represent oögonia in different stages of maturity. (Highly magnified.) (*After Thuret.*)

an aperture at its summit which leads into an enclosed cavity within the receptacle. This cavity is called the *conceptacle*. Within the conceptacles of the male plants of the species the *antheridia*, or male sexual organs, are formed while in the conceptacles of female plants the *oögonia* or female sexual organs, are produced. The conceptacles also contain numerous, branching, protective filaments called *paraphyses*, which arise from the cells lining the cavities. The antheridia are found as outgrowths of some of these paraphyses and produce *sperms* or male sexual cells. The *oögonium* is a large, globular, stalked cell and produces eight *eggs*, each of which is a female sexual cell. The eggs and sperm escape into the sea water.

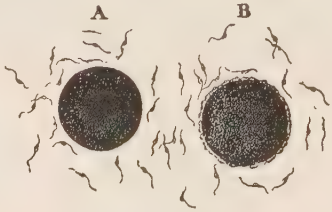

FIG. 210.—*Fucus vesiculosus*. Fertilization. *A*, egg approached by biciliated sperms; *B*, sperms attached to egg and surrounding it prior to fertilization (highly magnified). (*After Thuret.*)

The eggs float and are surrounded by myriads of sperms. One sperm, only, gains an entrance, after which its nucleus fuses with that of the egg to form an oöspore. The oöspore at once develops into a new Fucus plant.

The drug **Fucus** of the National Formulary consists of the dried thallus of *Fucus vesiculosus*, *Fucus serratus*, *Fucus nodosus* or *Fucus siliquosus* (Fam. *Fucaceæ*). Fucus is used in the treatment of obesity and goiter.

CLASS V.—RHODOPHYCEÆ, THE RED ALGÆ

A greatly diversified group comprising the majority of marine algæ but represented also by some fresh-water forms. The marine red algæ are generally found at or just beyond the low water mark. Their vegetative bodies vary from simple branching filaments through all gradations to forms differentiated into holdfasts and

branching stem- and leaf-like structures. It has been observed that many of the higher types are composed of numerous filaments which are arranged so closely and connected so intimately by protoplasmic processes as to superficially resemble the tissues of plants of higher domain. Their color may be red, purple, violet, or reddish-brown or even green and is due to the presence of *phycoerythrin*, a

FIG. 211.—*Chondrus crispus.* (*After Strasburger.*)

red pigment, which is found in the chromatophores with, but frequently masking, the chlorophyll.

Chondrus crispus and Gigartina mamillosa, when dried and bleached, constitute the official drug **Chondrus,** Irish Moss or Carragheen. Both are purplish-red in color. Each consists of a dichotomously branched thallus the lower portion of which is differentiated as a stipe or stalk; the basal portion of which, called the holdfast, clings to the rock. The upper part is several times forked and

its terminal segments appear notched or bilobed. Scattered here and there over the segments of the thallus will be noted sporangia which, when mature, contain *tetraspores*. In *Chondrus crispus* the sporangia are elliptical and embedded in the thallus near its surface, whereas in *Gigartina* they are ovate and borne on minute stalks which project outward from the surface of the segments. Upon the ripening of these structures the spores are discharged into the sea water. These sooner or later germinate into new *Chondrus* or *Gigartina* organisms.

FIG. 212.—*Gigartina mamillosa*. *s*, fruiting body consisting of short projection bearing tiny sporangia. (*After Strasburger.*)

The dried mucilaginous substance extracted from *Gelidium corneum* other species of *Gelidium* and closely related red algæ growing in the sea along the eastern coast of Asia and along the coast of California constitutes the drug, **Agar.** Agar is a most valuable ingredient in culture media as well as a laxative.

Rhodymenia palmata or **Irish Dulse** is a purplish-red, flat, membranous, palmately cleft or dichotomous red alga growing on the tissues of other algæ along northern shores of the Atlantic between the low- and high-tide marks.

CHAPTER XVIII

THE FUNGI

The fungi constitute a great assemblage of thallophytes which are characterized by the total absence of chlorophyll. The members of this subdivision, therefore, possess no independent power of manufacturing food materials such as starches, sugars, etc., from CO_2 and H_2O. Consequently they are either *parasites*, depending for their nourishment upon other living plants or animals, called *hosts;* or *saprophytes*, depending upon decaying animal or vegetable matter in solution. Some forms are able to live either as saprophytes or parasites while others are restricted to either the parasitic or saprophytic habit. Some of the fungi like the bacteria and the yeasts are unicellular while others like the molds and mildews, etc. have bodies in the form of thread-like filaments called *hyphæ* (sing. *hypha*) which are frequently branches. A mass of intertangled hyphæ is called a *mycelium*. The hypha may be unicellular or multicellular. Fungal hyphæ either ramify through decaying matter or invade the tissues of living organisms and derive nourishment therefrom. In the cases of parasitic fungi like the rusts, etc., absorbing connections are present as hyphal outgrowths which penetrate into the cells of the host plant. These are called *haustoria*. In the higher forms the hyphæ become consolidated into false tissues, and assume definite shapes according to the species. Of this character are the fruiting organs which constitute the above ground or exposed parts of Puff Balls, Cup Fungi, Mushrooms, etc.

There are three classes of fungi, viz.:

Class I Schizomycetes (bacteria)
Class II Myxomycetes (slime moulds)
Class III Eumycetes (true fungi)

Class I.—Schizomycetes (Bacteria)

The bacteria, also called "schizomycetes" or "fission fungi," are now regarded by leading systematists as the lowest types of plant life extant. Among them are to be found the smallest living organisms known to science.

Bacteria are minute, unicellular, colorless, rarely weakly red or green colored, vegetable organisms destitute of chlorophyll. They serve as agents of decay and fermentation and are frequently employed in industrial processes. The curing of certain drugs and

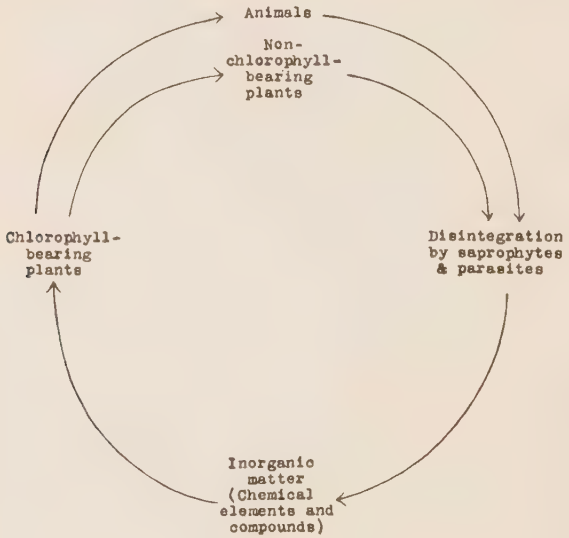

Fig. 213.—The organic cycle. (*After Gager.*)

tobacco, the tanning of leather, the manufacture of vinegar, buttermilk, cheese and indigo and the retting of flax and some other textile fibers are all dependent upon fermentative processes induced by bacteria. Their form varies from spherical, rod-shaped, spiral to filamentous, the filamentous types being frequently surrounded by a capsule or sheath.

The bodies of most bacteria possess nitrogenous cell walls, although hemicellulose has been found in the walls of many. Cytoplasm

occurs within the cell as well as chromatin, but the latter is usually diffused in fine particles through the cell protoplasm and never has been demonstrated to be condensed into a definitely organized body called a nucleus. A common method of asexual reproduction is possessed by these plants whereby the cell cleaves or splits into two parts, each of which becomes a separate and independent organism. Sexual reproduction is absent. Bacteria occur everywhere but are relatively few on high mountain peaks and beneath 3 meters of natural soil.

According to the various phenomena they produce, they may be classified as follows: (*a*) Zymogens producing fermentation; (*b*) Aerogens producing gas; (*c*) Photogens producing light; (*d*) Chromogens producing color; (*e*) Saprogens, producing putrefaction; (*f*) Pathogens, producing disease; (*g*) Thermogens, producing heat.

Bacterial Cultures.—Because of their minute size (a space the size of a pinhead may hold eight billion of them), the student commences his study of bacterial growths in colonies or cultures, each kind possessing characteristics by which they may be distinguished and differentiated. These cultures are obtained by growing the microorganisms on sterile artificial culture media usually in an incubator, the temperature of which is carefully regulated to suit the requirements of the organisms grown. The culture media employed are both solid and liquid. Beef broth or nutrient bouillon forms the basis of most of the culture media. To this either agar agar or gelatin are added to solidify the medium (solid media) and various chemical substances and sugars for the purpose of studying the physiological characteristics of the various forms. Formulas for the preparation of various culture media and directions for the isolation of bacteria will be found in works of bacteriology and mycology.

Forms of Bacteria.—Bacteria occur as spheres, straight rods or cork-screw like (bent rods) forms (lower bacteria) or as filaments (higher bacteria). The spherical shaped form is termed a *micrococcus* or *coccus* (plural-*micrococci* or *cocci*). The straight rod form is called a *bacillus* (plural-*bacilli*). The cork-screw shaped form is known as a *spirillum* (plural-*spirilla*).

Motility.—A large number of bacteria possess the power of independent movement when observed in a fluid medium which will

permit of their locomotion. This true movement should be distinguished from the so-called "Brownian movement," a phenomenon shown by minute particles or bodies when freely suspended in a suitable fluid. True movement is due to the activity of the living cell, whereas Brownian movement is a purely physical phenomenon due to surface tension. In true movement the individual form moves

FIG. 214.

FIG. 215.

FIG. 214.—Monotrichous bacteria. *Microspira comma.* (*After Migula from Schmidt and Weiss and Marshall.*)

FIG. 215.—Lophotrichous bacteria. *Pseudomonas syncyanea.* (*After Migula from Marshall.*)

FIG. 216.

FIG. 217.

FIG. 216.—Lophotrichous bacteria. *Spirillum rubrum.* (*After Migula from Schmidt and Weiss and Marshall.*)

FIG. 217.—Peritrichous bacteria. *Bacillus typhosus.* (*After Migula from Schmidt and Weiss and Marshall.*)

from one part of the microscopic field to another, whereas in Brownian movement the individual forms do not change their relative positions to any extent.

The power of locomotion which certain bacteria possess is due to the possession by these forms of fine protoplasmic extensions from their bodies which are thought to pass from the cytoplasm through the cell wall into the surrounding liquid medium. These are called

flagella or *cilia*. They are endowed with the power of contractility, and through their vibratory motion the organism is enabled to propel itself through the fluid medium. The great majority of bacteria possessing flagella are the bacilli and spirilla. These flagella are rarely seen without special methods of treatment and staining (see p. 352).

The distribution of flagella varies in different forms of bacteria. Some possess a single flagellum at one pole and are called *monotrichous*. When a flagellum occurs at each pole, they are termed *amphitrichous;* when a tuft occurs at one pole, *lophotrichous;* and when they occur over the whole cell, as in the case of the typhoid bacillus, *peritrichous*.

The motility or non-motility of bacteria is best determined through the examination of a hanging drop.

Nutrition.—Most bacteria derive their sustenance from organic substances. Those which obtain their nourishment from dead organic substances are termed *saprophytic bacteria* and those which obtain their nourishment from living organic material, *parasitic bacteria*. A number of the saprophytic forms will thrive both on living and dead organic matter and so are called *facultative parasites*, while many others, like the majority of the common soil and water bacteria, are restricted to dead organic matter and so are *obligate saprophytes*. Most of the parasitic bacteria are *facultative saprophytes*, since they can be grown upon artificial culture media. The leprosy bacillus is one of the few examples of parasitic bacteria which has resisted attempts to grow upon artificial culture media and so is an *obligate parasite*.

There occur a group of soil bacteria called *nitrifying bacteria* which thrive in the presence of simple inorganic salts and in the entire absence of organic matter. Some of these (*Nitrosomonas* and *Nitrosococcus*) oxidize the ammonia of the soil to nitrous acid or nitrites while others (*Nitrobacter*) convert the nitrous acid or nitrites to nitric acid or nitrates.

The products resulting from bacterial growth include pigments, enzymes, acid and alkali, putrefactive substances, ptomaines and toxins.

Reproduction.—Bacteria multiply and reproduce themselves by cleavage or fission. A young individual increases in size up to the limits of the adult form, when by simple cleavage at right angles to the long axis, the cell divides into two individuals.

Morphology Due to Cleavage.—According to limitations imposed by cleavage directors, the spherical forms called micrococci or cocci assume a chain appearance, or a grape cluster-like appearance, or an arrangement in packets or cubes having three diameters. These aggregations are the basis for the following genera of spherical-shaped bacteria:

FIG. 218.—Division forms of micrococci. *a*, Diplococcus, perfect form with flattened opposed surfaces (*gonococcus*), lanceolate form (*pneumococcus*); *b*, streptococcus; *c*, consecutive fission yielding a *tetrad*; *d*, *sarcina* form resulting from division of a tetrad; *e*, staphylococcus. (*From Marshall after Novy.*)

Staphylococcus (plural, *staphylococci*), from a Greek word referring to the shape of a bunch of grapes.

Streptococcus (plural, *streptococci*) from a Greek word meaning chain-shaped.

Sarcina, package-shaped or cubical.

Form of Cell Groups after Cleavage.—The individual bacteria after cleavage may separate, or cohere. The amount of cohesion, together with the plane of cleavage, determines the various forms of the cell groups. Thus, among the cocci, diplo- or double forms may result giving rise to distinguishing morphological characteristics. Similarly, among the bacilli, characteristic forms result as single individuals and others which form chains of various lengths.

Sporulation.—A large number of bacteria possess the power of developing into a resting stage by a process known as sporulation or spore formation. Sporulation is regarded as a method of resisting unfavorable environment. This is illustrated by the anthrax bacilli which are readily killed in twenty minutes by a 10 per cent.

solution of carbolic acid, and able, when in the spore condition, to resist the same disinfectant for a long period in a concentration of 50 per cent. While the vegetative forms of anthrax show little more resistance against moist heat than the vegetative form of other bacteria, the spores will withstand the action of live steam for as long as ten to twelve minutes or more.

Whenever the spores are brought into favorable condition for bacterial growth, as to temperature, moisture and nutrition, they return to the vegetative form and then are capable of multiplication by fission in the ordinary way.

FIG. 219.—Spores and their location in bacterial cells. (*Marshall after Frost and McCampbell.*)

Two kinds of spores occur amongst bacteria, *arthrospores* and *endospores*. Arthrospores represent entire bacterial vegetative cells which lose some of their water and thicken their walls and thus become resting cells. Endospores or true spores of bacteria are formed within the cell. They have the power of resisting a greater heat than the arthrospores.

Rapidity of Growth and Multiplication.—The rapidity with which bacteria grow and multiply is dependent upon species and environment. The rapidity of the growth is surprising. Under favorable conditions they may elongate and divide every twenty or thirty minutes. If they should continue to reproduce at this rate for twenty-four hours, a single individual would have 17 million descendants. If each of these should continue to grow at the same rate, each would have in twenty-four hours more, 17 million off-

spring, and then the numbers would develop beyond conception. However, such multiplication is not possible under natural or even artificial conditions, both on account of lack of nutritive material and because of the inhibition of the growth of the bacteria by their own products. If they did multiply at this rate, in a few days there would be no room in the world but for bacteria.

Chemical Composition of Bacteria.—The quantitative chemical composition of bacteria is subject to wide variations, dependent upon the nutritive material furnished them. About 80 to 85

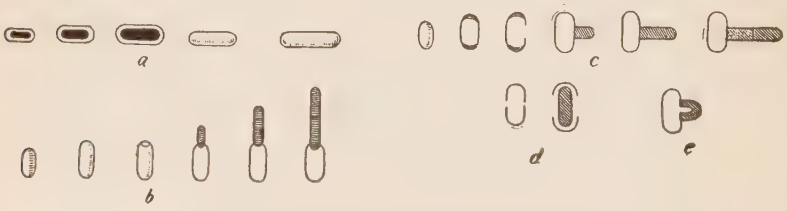

FIG. 220.—Spore germination. *a*, direct conversion of a spore into a bacillus without the shedding of a spore wall (*B. leptosporus*); *b*, polar germination of Bact. anthracis; *c*, equatorial germination of *B. subtilis* (hay bacillus); *d*, same of *B. megaterium*; *e*, same with "horse-shoe" presentation. (*From Marshall after Novy.*)

per cent. of the bacterial body is water; proteid substances constitute about 50 to 80 per cent. of the dry residue. When these are extracted, there remain fats, in some cases wax, in some bacteria traces of cellulose appear, and the remainder consists of 1 to 2 per cent. ash.

The proteids consist partly of nucleo-proteids, globulins, and protein substances differing materially from ordinary proteids. Toxic substances known as *endotoxins*, to distinguish them from the *exotoxins* or bacterial poisons secreted by certain bacteria like the tetanus and diphtheria organisms during the process of growth, also occur.

MORPHOLOGICAL CLASSIFICATION OF BACTERIA

THE LOWER BACTERIA

The lower bacteria comprise most of the forms which produce disease and the majority of the forms which are used in the arts and

industries. They are grouped under the first 3 families, viz., *Coccaceæ*, *Bacteriaceæ* and *Spirillaceæ*.

Family I.—Coccaceæ.—Cells in their free condition globular, becoming but slightly elongated before division. Cell-division in one, two or three directions of space.

A. Cells without Flagella.

1. Division only in one direction of space forming an aggregation resembling a chain of beads—*Streptococcus*.

2. Division in two directions of space forming an aggregation resembling a cluster of grapes—*Staphylococcus*.

FIG. 221.—Types of bacilli. (*After Williams.*)

3. Division in three directions of space forming a package-shaped or cubical aggregation—*Sarcina*.

B. Cells with Flagella.

1. Division in two directions of space—*Planococcus*.

2. Division in three directions of space—*Planosarcina*.

Family II.—Bacteriaceæ.—Cells longer than broad, generally two to six times, straight or only with an angular bend, never curved or

FIG. 222.—Types of spirilla. (*After Williams.*)

spiral, division only at right angles to axis or rod; with or without flagella and endospores.

1. Flagella and endospores absent—*Bacterium*.

2. Flagella and endospores present.

(*a*) Flagella over entire surface—*Bacillus*.

(*b*) Flagella at one end—*Pseudomonas*.

Family III.—Spirillaceæ.—Cells curved or spirally bent, generally motile through polar flagella.

1. Cells stiff, not flexile.
   (*a*) Cells without flagella—*Spirosoma.*
   (*b*) Cells with one, very rarely with two polar flagella—*Microspira* (*Vibrio*).
   (*c*) Cells with a bundle of polar flagella—*Spirillum.*
2. Cells flexile, spiral very close—*Spirochæta.*

FIG. 223.—*Crenothrix polyspora,* an iron bacterium, which oxidizes iron causing a deposit of iron hydroxide to accumulate in water pipes where it may cause trouble. (*After Migula from Schmidt and Weiss and Marshall.*)

THE HIGHER BACTERIA

Family IV.—Mycobacteriaceæ.—Cells short or long, cylindrical or clavate-cuneate in form, without a sheath surrounding the

chains of individuals, without endospores, with true dichotomous branching.

A. In cultures possessing the characters of true bacteria. Growth on solid media smooth, flat, spreading. Rod with swollen ends, or cuneate or clavate forms—*Corynebacterium.*

B. Cultures on solid media raised, folded or warty. Generally short slender rods, rarely short branched. Take the tubercle stain—*Mycobacterium.*

Family V.—Chlamydobacteriaceæ.—Thread-like, composed of individual cells, surrounded by a sheath. Simple or with true

FIG. 224.—Sulphur bacteria (*Beggiatoa alba*). (*After Winogradsky from Schmidt and Weiss and Marshall.*)

branching. Ordinary vegetative growth by division in only one direction of space, *i.e.*, at right angles to the longer axis.

A. Cell contents without sulphur granules.

1. Filaments unbranched.

(*a*) Cell-division only in one direction of space.

(*b*) Cell-division in gonidial formation in three directions of space—*Streptothrix* (*Actinomyces*).

*Marine forms with cells surrounded by a very delicate hardly discernible sheath—*Phragmidiothrix.*

**Fresh-water forms with easily discernible sheath *Crenothrix.* (*Iron bacteris.*)

2. Filaments branched.

B. Cell contents with sulphur granules—*Thiothrix.*

Family VI.—Beggiatoaceæ (Sulphur Bacteria).—Thread-like, without a capsule, but with an undulating membrane. Cell contents show sulphur granules.

A. Threads apparently not septated, septa only faintly visible with iodine staining. Colorless or faintly rose-colored *–Beggiatoa.*

Some Bacteria Producing Diseases in Man or the Lower Animals

Organism	*Disease*
Staphylococcus pyogenes aureus	Boils, abscesses, carbuncles
Streptococcus erysipelatis	Erysipelas
Micrococcus meningitidis	Cerebrospinal meningitis
Micrococcus gonorrhœæ	Gonorrhœa
Micrococcus melitensis	Malta fever
Micrococcus catarrhalis	Catarrh
Bacterium anthracis	Anthrax
Bacterium diphtheriæ	Diphtheria
Bacillus typhosus	Typhoid fever
Bacterium influenzæ	Influenza
Bacillus tetani	Tetanus
Bacillus lepræ	Leprosy
Bacillus chauvei	"Blackleg" of cattle
Bacillus aërogenes capsulatus	Emphysematous gangrene
Bacterium tuberculosis	Tuberculosis
Bacterium mallei	Glanders
Streptococcus pneumoniæ (Diplococcus pneumoniæ)	Pneumonia (croupous or fibrinous pneumonia)
Spirillum choleræ asiaticæ	Cholera
Spirillum obermeieri	Relapsing fever
Streptothrix (Actinomyces) bovis	Actinomycosis in cattle

Some Bacteria Producing Diseases in Plants

Actinomyces Myricarum	Tubercles upon and lesions within Myrica and Comptonia
Bacterium tumefaciens	Crown gall
Bacterium savastanoi	Olive knot
Bacillus amylovorus	Pear blight
Pseudomonas juglandis	Walnut blight
Bacillus Solanacearum	Wilt of Solanaceæ
Bacillus tracheiphilus	Wilt of Cucurbits
Pseudomonas Stewarti	Wilt of Sweet Corn

Mounting and Staining of Bacteria.—The mounting and staining of bacteria may be accomplished as follows:

1. Take the square or round cover slip, which has been previously cleaned out of the alcohol pot. Dry it between filter paper.

2. Hold it in the bacteriologic forceps, which is so constructed that a spring holds the cover slip firmly while an enlargement of the wire handle permits the placing of the forceps on the table while the culture material is obtained.

3. Place several drops of distilled water on the cover slip and add a loop full of the organism secured from the pure culture in a test tube as follows:

4. Remove the cotton plug by the third and fourth fingers of the left hand.

5. Hold the open test tube between the thumb and forefinger of the left hand.

6. By means of a previously flamed platinum needle, remove a little of the culture from the surface of the culture media.

7. Replace the co ton plug.

8. Add the culture media to the drop of distilled water on the cover slip and distribute this material by stirring.

9. Evaporate the water on the cover slip to dryness by holding it some distance above the Bunsen flame and slowly enough to prevent connection circles being formed by the material affixed to the cover.

10. Pass the cover glass three times through the Bunsen flame.

11. Apply the stain, which should remain long enough to stain the objects.

12. Wash off the stain with distilled water.

13. Dry the cover glass above the flame.

14. Apply a drop of balsam, turn the cover slip over and drop it on to the center of a glass slide previously provided and cleaned for this purpose.

Gram's Method.—This is a method of differential bleaching after a stain. The cover preparations or sections are passed from absolute alcohol into Ehrlich's anilin gentian violet, where they remain one to three minutes, except tubercle bacilli preparations which remain commonly twelve to twenty-four hours. They are then placed for one to three minutes (occasionally five minutes) in iodine potassium iodide water (iodine crystals 1, potass. iodide 2, water 300), with or without washing lightly in alcohol. In this they remain one to three minutes. They are then placed in absolute alcohol until sufficiently bleached, after which they are cleared in clove oil and mounted in balsam.

Certain organisms, when stained by this method, give up the stain and are called "Gram negative;" others retain the color and are called "Gram positive." Examples of the latter are B. diphtheriæ, Bacillus anthracis, and Bacillus tetani.

Stains.—One of the most useful bacteriologic stains is *Ziehl's Carbol Fuchsin* prepared as follows:

Fuchsin (basic), 1.

Absolute Alcohol, 1.

Carbolic Acid (5 per cent. aqueous solution), 100.

The fuchsin should be dissolved first in the alcohol and then the two fluids mixed.

Ehrlich's Anilin Water Gentian Violet.—Anilin Oil Water, 75 parts.
Sat. Sol. Gentian Violet in Alcohol, 25 parts.
Anilin oil water is made by adding 2 cc. anilin to 98 cc. distilled water; shake violently. Filter through filter paper several times.

Löffler's Methylene-blue.—

Sat. sol. Methylene-blue in Alcohol	30
Sol. KOH in distilled water (1: 10,000)	100 cc.

Mix the solutions.

Stain for "Acid Proof" Bacteria Including B. Tuberculosis.—
1. Flood the cover glass with Ziehl's carbol fuchsin and boil over the flame for thirty seconds.
2. Wash and decolorize with a 2 per cent. solution of HCl in 80 to 95 per cent. alcohol until the thinner portions of the film show no red color.
3. Wash in water.
4. Counter stain for contrast with Löffler's Methylene blue.
5. Wash and examine.

Van Ermengem's Flagella Stain.—1. Mordant:

Osmic acid (2 per cent. aqueous solution)	50
Tannin (10 to 25 per cent. in water)	100

Four drops of glacial acetic acid may be added to this.
2. Silver Bath:
Dissolve 0.25 to 0.5 per cent. nitrate of silver in distilled water in a clean bottle.
3. Reducing and Strengthening Bath:

Gallic acid	5
Tannin	3
Fused sodium acetate	10
Distilled water	350

The flamed cover glass is first covered with the mordant for one-half hour, or if in a thermostat at 50°C., for five to ten minutes. The mordant is then carefully removed by thorough washing in water, alcohol and water. The cover (film side up) is now put into the silver bath (a few cc. in a clean beaker or watch glass) for a few seconds, during which time it is gently agitated. Without rinsing it is next put into a few c. c. of the reducing solution and gently agitated until the fluid begins to blacken. It is then washed in water and examined. If not stained deeply enough the cover is returned to the silver bath. It is finally dried and mounted in balsam. All the dishes must be scrupulously clean. The fluids must not be contaminated by the fingers nor by dipping iron or steel instruments into them.

Broca's Differential Stain.—

Löffler's Methylene Blue	80 cc.
Ziehl's Carbol Fuchsin	10 cc.

Mix the solutions.

This stain differentiates between dead and living bacteria. Dead bacteria take on a red coloration and living bacteria a blue color.

Class II.—Myxomycetes, or Slime Molds

Terrestrial or aquatic organisms, frequently classified as belonging to the animal kingdom and found commonly on decaying wood, leaves, or humous soil in forests. Their vegetative body consists of a naked, multinucleated mass of protoplasm called the *plasmodium*, which has a creeping and rolling amœboid motion, putting out and retracting regions of its body called *pseudopodia*. The size of

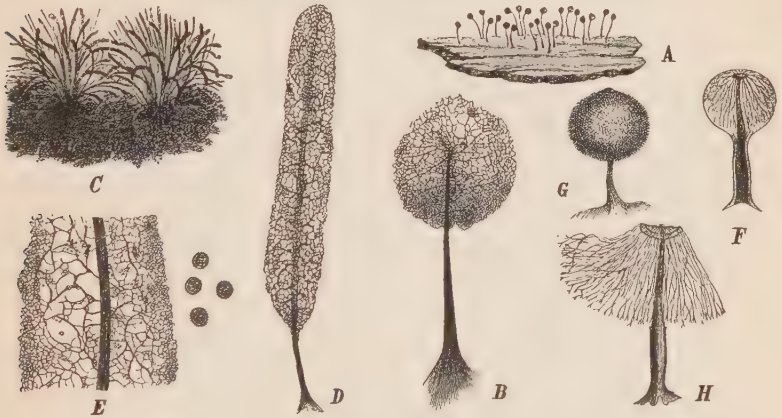

Fig. 225.—Slime molds. *A*, *B*, *Comatricha nigra*. *A*, Sporangium, natural size; *B*, capillitium, 20/1; *C*, *E*, *Stemonitis fusca;* *C*, sporangium, natural size; *D*, and *E*, capillitia, 5/1, 20/1; *F*, *H*, *Enerthema papillatum*, *F*, unripe; *G*, mature sporangium, 10/1; *H*, capillitium, 20/1. (*C*, *D*, *after nature*. *A*, *F*, *G*, *H*, *after Rostafinski;* *B*, *E*, *after de Bary in Die natürlichen Pflanzenfamilien* I. 1, p. 26.)

the plasmodium varies from a ten-cent piece to several square feet of surface. It is net-like, the net being of irregular dimensions. Like the amœba the outer portion of the plasmodium is clear and watery and known as the *ectoplasm*, the inner portion is granular and called the *endoplasm*. Like the amœba and unlike other plants, this slimy body engulfs solid food by means of its pseudopodia instead of admitting it in solution. It is extremely sensitive to light being negatively heliotropic, *i.e.*, turning away from the sun's rays. At the time of reproduction, the plasmodium creeps to the

surface. The whole plasmodium then forms one or more fructifications. These fructifications vary from cushion-like masses (*æthallia*) to more elevated bodies in which the net-like structure of the plasmodium is preserved (*plasmodiocarps*) to stalked *sporangia* (spore cases). All of the fructifications, however, produce *spores*. During wet weather amœboid protoplasts (*swarm spores*) escape from the spores, each developing a single *cilium* and moving actively about. In time the cilia disappear and these swarm spores coalesce in smaller then larger groups to form a plasmodium.

Class III.—Eumycetes (True Fungi)

The True Fungi represent a large class of chlorophylless plants in which are included plants ordinary called fungi, such as the molds, water-molds, yeasts, blights, mildews, rusts, smuts, toadstools, puffballs, etc. In nutrition, they are either saprophytes or parasites or may be adapted to both modes of existence. Most of them have a vegetative body called a mycelium consisting of filamentous hyphæ. This class is subdivided into the following sub-classes:

Sub-Class I. Phycomycetes or Alga-like Fungi—molds, water-molds, blights, mildews, rots.

Sub-Class II. Ascomycetes or Sac-Fungi—yeasts, powdery mildews, cup-fungi, morels, etc.

Sub-Class III. Basidiomycetes or Club-Fungi—smuts, rusts, mushrooms, puff-balls, etc.

Sub-Class IV. Deuteromycetes or Imperfect Fungi—fungi whose life histories are incompletely known, as celery-blight, etc.

The Phycomycetes, or Alga-like Fungi

The Phycomycetes represent a small group of fungi showing close affinity with the green algæ. Their mycelium is composed of hyphæ which are unicellular and many-nucleated up until the time of reproduction. This suggests a close relation with the Spihonales group of green algæ. Their sexual organs are likewise similar in structure. Transverse septa appear in the hyphæ upon the formation of reproductive organs which separate these structures from

the vegetative hyphæ. They reproduce by spores as well as by sexual reproduction.

Those Phycomycetes in which sexual reproduction is brought about through the union of like gametes belong to the order called *Zygomycetales* which includes the black bread molds and their kin; those in which sexual reproduction takes place through the union of unlike gametes belong to the *Oömycetales* or order of the water-molds and their allies.

The Black Bread Mold.—Rhizopus nigricans (*Mucor stolonifer*), commonly known as "Black Mold" or "Black Bread Mold," is frequently found on bread, jellies, syrups, acetic pharmaceutical

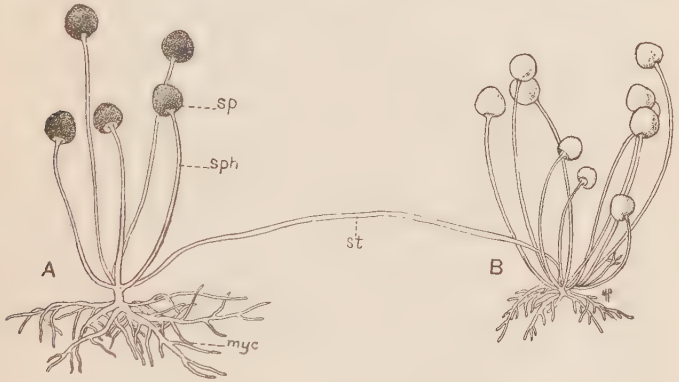

FIG. 226.—Black mold (*Rhizopus nigricans*). *A*, older plant; *myc*, mycelia; *sph*, sporangiophore; *sp*, sporangium; *st*, stoloniferous hypha produced by *A*, and giving rise at its tip to a new plant, *B*. Greatly enlarged. (*Gager.*)

extracts and other substrata, where it forms a dense thready *mycelium* bearing numerous black, tiny spore cases. The source of this mold is the spores, which are found in the air or water with which the attacked substratum is in contact. Each of these, upon germinating, sprouts out and forms three kinds of hyphæ, viz.: *rhizoidal* or *submerged hyphæ*, *sporangiophores* or *aerial hyphæ* and *stoloniferous hyphæ*. The branching rhizoidal hyphæ penetrate the substratum and secrete a diastatic ferment that changes the water insoluble carbohydrate materials into a soluble sugar which passes into solution and is absorbed by their walls. This, upon entering the hyphæ, is con-

verted into protoplasm, and so the mold increases in size. Sporangiophores or aerial hyphæ arise vertically or obliquely from a bulged-out common base of the rhizoidal hyphæ. Each of these when mature bears upon its summit a spheroidal *sporangium* containing numerous small, brownish, multinucleate spores called *endospores*. The wall of the sporangium is beset with asperites of calcium oxalate. Springing from the base of the sporangiophores or aerial hyphæ, one or more stoloniferous hyphæ traverse a portion of the surface of the substratum and their tips, coming in contact with the substratum, swell up forming an adhesive organ or *appressorium* which branches out below into a cluster of spreading submerged hyphæ and above into several aerial hyphæ bearing sporangia. This

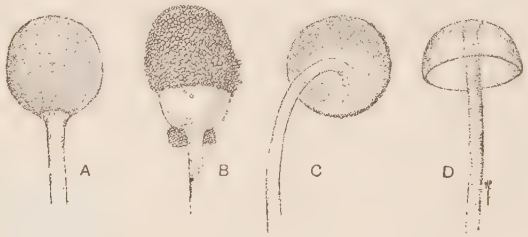

FIG. 227.—*Rhizopus nigricans*. *A*, Young sporangium, showing columella within; *B*, older sporangium, with the wall removed, showing ripe spores covering the columella; *C*, *D*, views of the collapsed columella after dissemination of the spores. (*Gager*.)

method of growth proceeeds until the entire surface of the nutritive medium is covered with a dense fluffy mycelium.

Rhizopus reproduces by two methods. The most common one is that of internal cell formation. In this asexual method a transverse wall is laid down in the sporangiophore near its tip. The terminal cell thus formed swells up, becoming globular in shape and its protoplasmic contents become changed to form numerous spores within the wall of the sporangium or enlarged terminal cell of the sporangiophore. The partition wall, separating the lumen of the sporangium from that of the sporangiophore, bulges into the sporangium as a dome-shaped structure, which is termed the *columella*. Upon the ripening of the spores the wall of the spore case bursts, liberating them. These, falling upon moist nutrient substrata, germinate and

ultimately form new *Rhizopus* plants. Under certain conditions *Rhizopus* reproduces sexually. Thicker and shorter club-shaped hyphæ arise on opposite branches of the mycelium as lateral outgrowths. A partition wall is laid down in each of these a short distance from its tip and the contents of each end-cell then becomes a gamete or sexual cell. The apical cells of the tips of opposite hyphæ then meet, a solution of the cell walls at the point of contact takes place and the gametes of both end-cells fuse to form a *zygospore*

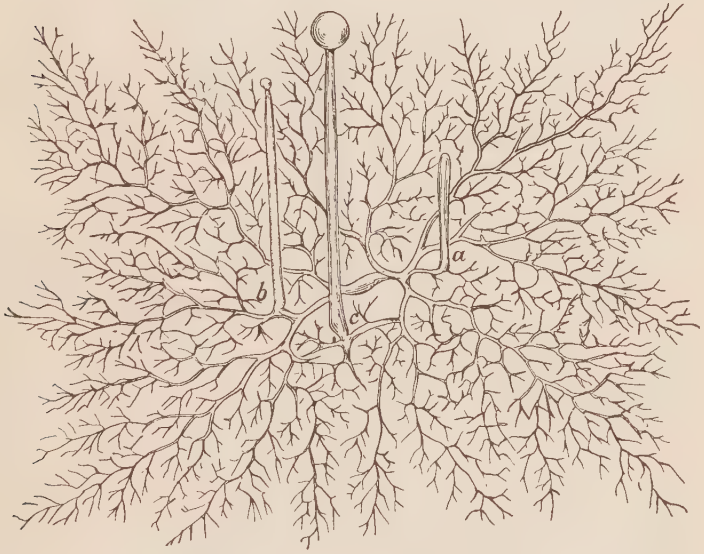

FIG. 228.—*Mucor mucedo*, showing mycelium and sporangiophores. (*Palladin.*)

This enlarges and develops a highly resistant wall. After a period of rest, upon coming into contact with a nutrient medium, it germinates into an elongated sporangiophore which develops a sporangium at its summit.

Rhizopus has been shown by Blakeslee to exhibit 2 kinds of mycelia that are designated as (+) and (−) strains, each of which arises from a different kind of spore. It is only when unlike strains occur together that zygospore formation actually occurs.

Mucor mucedo, another closely allied species, found growing on old nuts, fleshy fruits, bread and horse manure, resembles *Rhizopus nigricans* in many respects but differs from it by the formation of sporangiophores singly instead of in clusters.

Thamnidium differs from *Rhizopus* and *Mucor* in the development of two kinds of sporangia, *microsporangia* and *megasporangia*. The sporangiophore produces a terminal large megasporangium possessing a columella and whorls of side branches which bear smaller microsporangia in which the columella is frequently wanting.

The Ascomycetes or Sac Fungi

Mycelium composed of septate filaments and life history characterized by the appearance of a sac, called an *ascus*, in which *ascospores* are formed. The largest class of fungi.

Order 1.—**Protoascales.**—Plants with asci borne free or at the ends of hyphæ, definite fruiting bodies being absent. Each ascus usually develops four ascospores. To this order belong *Exoascus*, which is responsible for the abnormal development of tufted masses of branches on a number of trees and shrubs, and the *yeasts* (Saccharomycetaceæ) many of which produce fermentation.

Yeasts are unicellular plants of spheroidal, oval, elliptical, pyriform or sausage shape which reproduce by budding. They occur either in the wild or cultivated condition and are generally found capable of breaking down some form of sugar into alcohol and carbon dioxide.

According to the kind or kinds of sugar fermented Hansen, in 1888, classified the yeasts as follows:

1. Species which ferment dextrose, maltose and saccharose: *Saccharomyces cerevisiæ I, S. ellipsoideus I, S. ellipsoideus II, S. pastorianus I, S. pastorianus II, S. pastorianus III.*

2. Species which ferment dextrose and saccharose, but not maltose: *Saccharomyces marxianus, S. exiguus, S. saturanus, S. Ludwigii.*

3. Species which ferment dextrose, but neither saccharose nor maltose: *Saccharomyces mali Duclauxii.*

4. Species which ferment dextrose and maltose, but not saccharose: *Saccharomyces* n. sp. obtained from the stomach of the honey bee.

5. Species which ferment neither maltose, dextrose nor saccharose: *Saccharomyces anomalus var. belgicus, S. farinosus, S. hyalosporus, S. membranifaciens.*

The two most important yeasts in the fermentation industries are *Saccharomyces cerevisiæ* and *Saccharomyces ellipsoideus.*

Life History of a Yeast.—*Saccharomyces cerevisiæ,* commonly called Brewer's Yeast, is a cultivated species with many strains. It is used extensively in the brewing and baking industries and in recent years has met with considerable esteem by the medical profession in the treatment of certain skin diseases.

This plant may be readily grown by sowing a portion of a yeast cake in Pasteur's Solution. The flask is then stoppered with a pledget of cotton and set aside in a warm place.

Pasteur's Solution.—Ammonium tartrate, 5 Gm.; potassium phosphate, 1 Gm.; calcium phosphate, 0.1 Gm.; magnesium sulphate, 0.1 Gm.; sucrose, 75 Gm.; water, 419 Gm.

When examined under the microscope it is found to be somewhat spheroidal to ellipsoidal in outline, 8 to 12μ long, and 8 to 10μ broad. It consists of an outer cell wall of *fungous cellulose* enclosing cytoplasm and a nucleus, the latter invisible without special staining. The cytoplasm is differentiated into a clear outer membrane lying directly within the cell wall and termed the *ectoplasm* and an inner granular region, the *endoplasm.* In the young condition of the yeast cell numerous glycogen vacuoles are found scattered more or less uniformly throughout this region but as the cell matures these coalesce until, in a very old cell, a huge glycogen vacuole may be seen occupying most of the interior, with the cytoplasm and nucleus pushed up against the cell wall and forming there a very narrow layer.

Yeast plants grow in dilute saccharine solutions containing dissolved nitrogenous substances such as beerwort, Pasteur's solution, grape juice, etc. Here they are constantly wasting away and as constantly being built up. The question may well arise: "How do they obtain the material necessary for growth and repair?" The answer, in a general way, is not difficult. The fluid in which they live is a solution of sugars and of nitrogenous and other matters. The cell walls are readily permeable. Food substances diffuse

through it into the cell, and by a series of changes (which, indeed, it is no easy matter to understand) are converted into new living substance. The waste products likewise diffuse readily outward. This method of nutrition is called saprophytic, and the yeast plant is said to be a *saprophyte*.

FIG. 229.—Yeast, *Saccharomyces cerevisiæ*, the variety known as brewers' bottom yeast; *a*, spore formation; *b*, elongated cells. (*After Schneider, Pharmaceutical Bacteriology.*)

A striking fact must be briefly mentioned in connection with the metabolism of yeast. Many organisms exercise a profound effect on the medium in which they live. Yeast causes a wholesale destruction of sugar in the surrounding fluid. One of the decomposition products of sugar is alcohol. The alcohol of commerce is produced by the activity of this plant.

The protoplasm of the yeast plant manufactures two kinds of enzymes, viz., an extracellular enzyme called *invertase* which passes out of the yeast cell and hydrolyzes cane sugar to dextrose (invert sugar) and an endocellular enzyme called *zymase* which remains within the yeast cell and breaks down dextrose into alcohol and carbon dioxide.

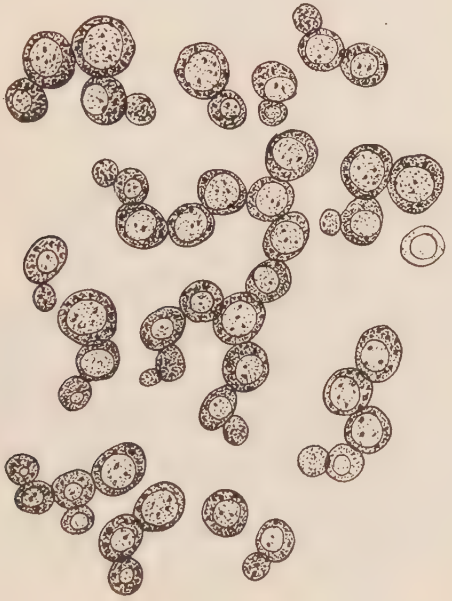

FIG. 230.—*Saccharomyces cerevisiæ.* The form or variety known as brewers' top yeast. (*Oberhefe.*)

Saccharomyces has its times of danger and stress when the cells perish in great numbers from cold, starvation, poisons, etc. If not too suddenly exposed, however, they are able to meet adverse conditions by eliminating most of their water, suspending physiological processes, and becoming dormant. Sometimes they enter the resting condition after a process of division, when each cell divides into four parts, each of which becomes nearly dry and is surrounded by a thick wall. Such cells are called *ascospores,* and their production serves both as a method of multiplying the plant and of tiding over

adverse conditions. They can survive for a long time without food or water, and can endure higher temperatures than the active cells and almost any degree of cold.

The dried cells and spores float in the air as dust and so accomplish a dispersal of the organism. Doubtless most of them never again meet suitable environment and so sooner or later perish. But some will fall into favorable conditions and be able to multiply enormously again, and so the species is continued.

The general method of reproduction in Saccharomyces is that of *gemmation* or *budding*. A small protuberance of the cell wall com-

FIG. 231.—*Saccharomyces ellipsoideus*. A common yeast found on grapes, jams, jellies, etc. Budding process is shown in many of the cells as also the vacuoles. (*Schneider, Pharmaceutical Bacteriology.*)

mences to form on the parent-cell. This grows larger and a portion of the cytoplasm and nuclear material pass into it. Eventually a daughter-bud, which may assume the size of the parent-cell, is formed. This generally adheres to the parent-cell and produces one or more granddaughter-buds which in turn may produce great-granddaughter-buds before separation from the parent-cell takes place.

There are two varieties of brewer's yeast, viz.: **Top yeasts** and **Bottom yeasts.** Top yeasts grow on or near the surface of the liquid

and produce rapid fermentation at summer temperatures causing great quantities of carbon dioxide to arise to the surface and thus forming the froth which is characteristic of ale, stout and porter.

Bottom yeasts grow at about 4°C. at or near the bottom of the vat. They are used in the manufacture of lager beers.

Compressed yeast (Cerevisiæ Fermentum Compressum) N. F. consists of the moist, living cells of *Saccharomyces cerevisiæ* or of other species of *Saccharomyces*, combined with a starchy or absorbent base.

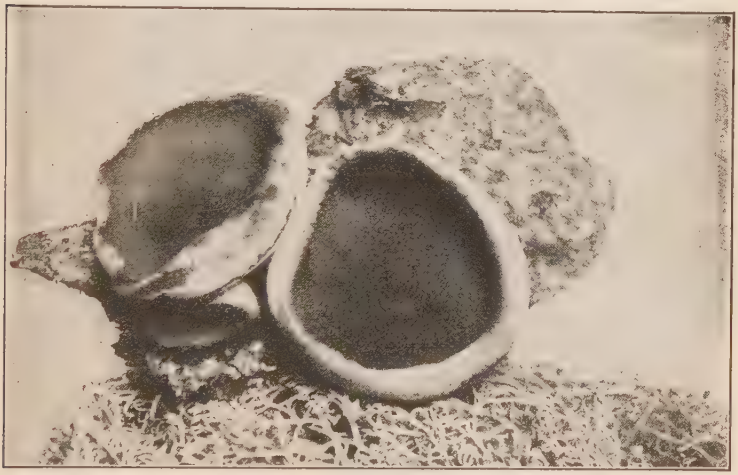

FIG. 232.—Saucer-shaped fruit-bodies of *Peziza repanda*. (*Harshberger, from Photo by W. H. Walmsley.*)

Other Yeasts.—*Saccharomyces ellipsoideus* is a wild species, several varieties of which are found growing on grapes especially in districts where wine is produced. It is termed the true wine yeast to distinguish it from other wild species found in grape juice, like *S. apiculatus* and *S. membranifaciens* which exert a deleterious effect in wine production. Its cells are ellipsoidal, 6μ long, occurring singly or in rows of several generations, which are rather loosely joined.

Order 2.—Pezizales or cup fungi. Examples: *Peziza*, *Lachnea* and *Ascobolus*.

Parasitic or saprophytic plants, whose vegetative bodies consist of a mycelium ramifying through the substratum and whose above ground fruiting bodies are sessile or stalked, cup or saucer-shaped

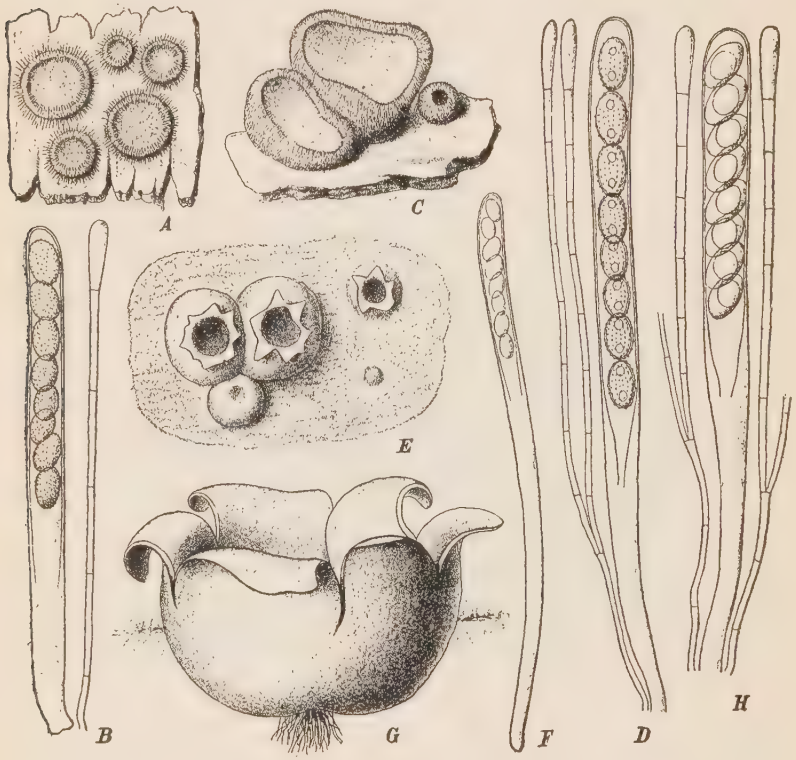

FIG. 233.—Cup Fungi. *A*, *B*, *Lachnea scutelata*. *A*, Habit; *B*, ascus with paraphysis; *C*, *D*, *Lachnea hemisphærica;* *C*, habit; *D*, ascus with paraphysis; *E*, *Sarcosphæra arenosa* habit; *F*. *G*, *Sarcosphæra coronaria;* *F*, ascus; *G*, habit; *H*, *Sarcosphæra arenicola* ascus with paraphysis. (*See Die natürlichen Pflanzenfamilien* I, 1, p. 181.) (*Harshberger.*)

structures termed *apothecia* (sing. apothecium), in which a fruiting membrane (*ascigeral layer*) lines the concave upper surface. The asci are usually eight-spored and separated from each other by filamentous structures called *paraphyses*. (Figs. 232 and 233.)

Order 3.—Plectascales, the blue and green molds. Examples: *Aspergillus* and *Penicillium.*

Penicillium glaucum (**green mold or mildew**), a type of mildew, belonging to the Ascomycetes class of Fungi, forms sage-green crusts on bread, jellies, old boots, gloves, and various pharmaceutical

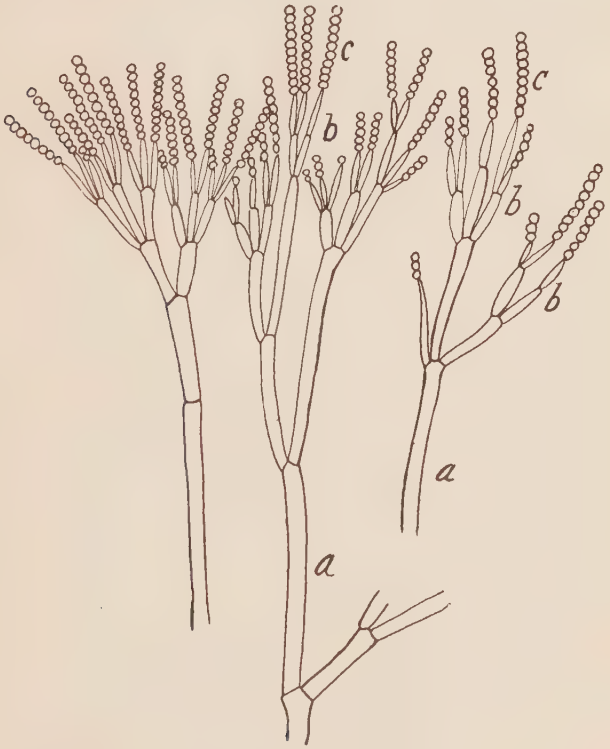

FIG. 234.—Three aerial hyphæ showing the characteristic brush-like branching and spore formation of *Penicillium glaucum.* This fungus is a true saprophyte and is never found on living fruits or vegetables. *a*, Conidiophore branching above into secondary conidiophores; *b*, sterigmata; *c*, conidiospores. (*Schneider.*)

preparations. It consists of a felt-like mass of interlaced tubular hyphæ called a *mycelium.* From the mycelium numerous hyphæ project into the air and bear a green powder, the spores. These hyphæ are called *aerial hyphæ.* Other hyphæ grow down into the substratum and are called *submerged hyphæ.*

When a small portion of the mycelium is mounted in 10 per cent. alcohol and observed under the high-power objective, it will be noted that each hypha has a transparent wall and protoplasmic contents and is divided by transverse septa into a number of cells. Each cell contains protoplasm, which is differentiated into cytoplasm (cell protoplasm) and several nuclei. In the cytoplasm will be seen several large clear spaces. These are vacuoles and contain water

FIG. 235.—*Penicillium Roqueforti*. *a*, Part of a conidiophore; *b*, *c*, other types of branching; *d*, young conidiophore, just branching, *e*, *f*, conidiiferous cells; *g*, *j*, diagrams of types of fructification. *k*, *l*, *m*, *n*, germinating spores. (*After Thom.*)

with nutritive substances in solution, called *cell sap*. Each hypha with its branches is clearly distinct from every other one.

The aerial hyphæ bear brush-like branches, which become constricted on their ends into a moniliform aggregation of rounded spores appearing like a row of beads. Each aerial hypha is composed of a vertical septate branch of the mycelium called the *conidiophore*, branches of this, which are called *secondary conidiophores*, and

chains of spores at the tips of *sterigmata* (cells bearing conidia) which are called *conidia* or *conidiospores*. The conidia form the loose green powder characteristic of Penicillium.

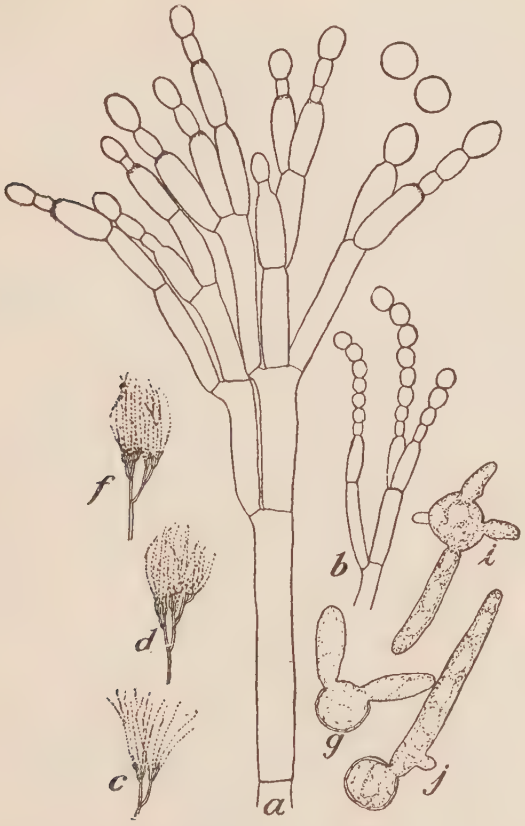

FIG. 236.—*Penicillium Camemberti*. *a*, Conidiophore with common type of branching with conidiospores; (*b*) a common less-branched form; *c*, *d*, *f*, diagrams of large fructifications; *g*, *i*, *j*, germinating conidiospores. (*From Bull. 82, Bureau of Animal Industry, also after Thom.*)

A number of species of *Penicillium* are useful in the arts. *Penicillium roqueforti* is the principal ripening agent of Roquefort, Gorgonzola and Stilton cheeses. It possesses blue-green globular conidia 4 to 5μ in diameter.

Penicillium camemberti is the principal agent in the ripening of Camembert cheese. It possesses ellipsoidal bluish-green conidia 4.5 to 5.5μ in diameter.

Penicillium brevicaule grows on old moist paper and has been used to detect the presence of arsenic, for when grown in media containing this element, it develops the compound, diethylarsine. It is yellowish-brown in color and its conidia are rough and spiny.

Penicillium expansum is often found on decaying apples where it produces brownish coremia.

Aspergillus herbariorum.—This green mold also named *Aspergillus glaucus* and *Eurotium Aspergillus glaucus* is frequently found on

FIG. 237.—*Penicillium brevicaule*. *a*, Conidiophores and simple chains of conidiospores; *b*, *f*, more complex conidial fructifications; *c*, two young chains of conidiospores; *d*, *e*, echinulate conidiospores; *g*, *h*, *j*, sketches of forms and habits of conidial fructifications; *k*, germinated conidiospores. (*After Thom.*)

fleshy drugs which have not been properly dried. It has also been observed on dried herbarium material, old extracts, on jams, jellies, tobacco, cotton-seed meal, old leather, stale black bread, etc. Like *Penicillium* its vegetative body consists of a mycelium consisting of aerial and submerged hyphæ. It differs from *Penicillium*, however, mainly in not possessing septated conidiophores and by the upper portion of the conidiophores being globular. Upon the globular extremity of the conidiophores are placed numerous elongated sterig-

mata which bear chains of grayish-green conidia. These are spherical and prickly and range from 7 to 30μ in diameter. Under certain

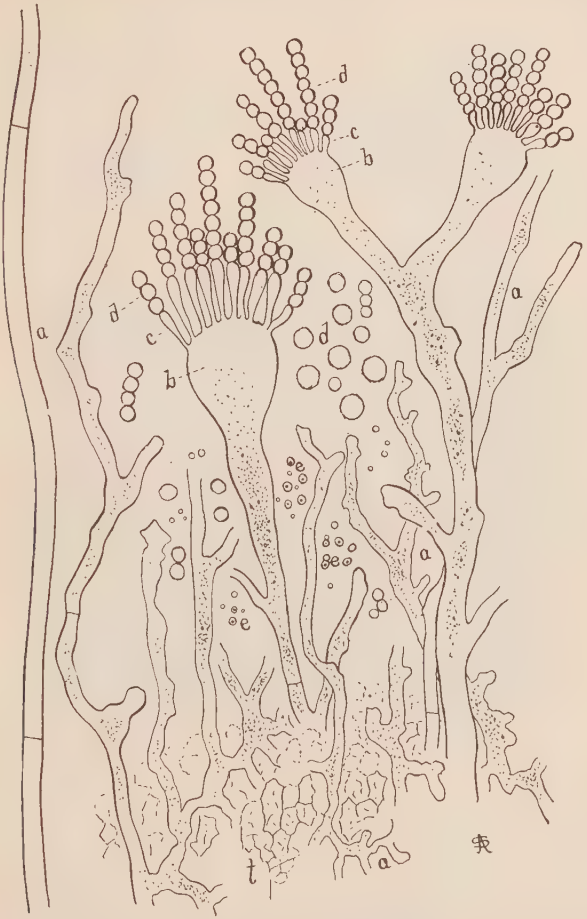

FIG. 238.—*Aspergillus oryzæ* associated with yeasts in the making of the Japanese beverage Saké. Vegetative hyphæ (*a*) and spore-forming hyphæ (*b*, *c*, *d*) are shown. (*Schneider, Pharmaceutical Bacteriology.*)

conditions closed brownish fruit bodies called *perithecia* are produced. These arise on the surface of the substratum from spirally coiled

hyphæ and when mature possess numerous *asci*, each of which contains five to eight ellipsoidal *ascospores*.

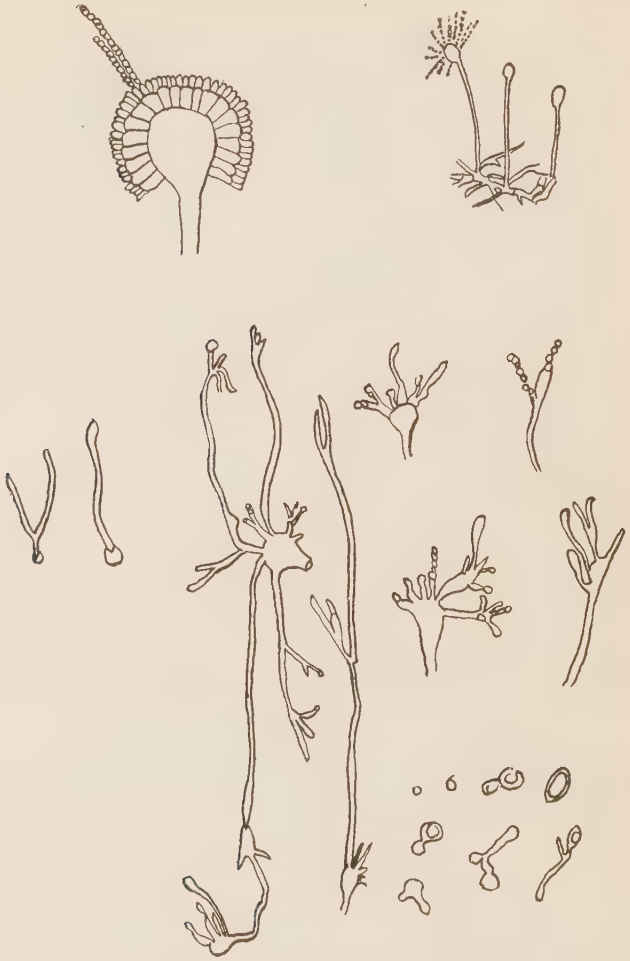

FIG. 239.—*Aspergillus niger* showing conidiophores and conidiospores formation with stages in germination of spores. (*Harshberger, after Henri Coupin.*)

Aspergillus oryzæ is a yellowish-green to brown mold which secretes diastase, a valuable digestive ferment, having the power of

converting starch into sugar and dextrin. For centuries the Japanese have employed this species in the preparation of rice mash for Saké, as well as in manufacture of Miso and Soja sauce. The spherical conidiospores are 6 to 7μ in diameter and of a yellowish-green color.

Aspergillus fumigatus is a pathogenic species which produces a disease in birds, horses, cattle and even, though rarely, in man that is called aspergillosis. The organ most prone to infection by this organism is the lung, although the skin, cornea, ears and other parts are also subject to its parasitic influence. It produces short coni-

FIG. 240.—The morel, *Morchella esculenta*. (*Gager, from photo by W. A. Murrill.*)

diophores with sterigmata bearing long chains of rounded, colorless conidia 2.5 to 3μ in diameter. Harshberger[1] cites the presence of perithecia in this organism which are nut-brown, globular, 250 to 350μ in diameter, and inclose oval, thin-skinned asci with eight red lenticular ascospores each of which has a diameter of 4 to 5μ.

Aspergillus niger develops dark brown mycelial masses in which are to be noted slender conidiophores bearing handle-shaped, branched sterigmata that cut off from their tips chains of rounded black-brown conidia 3.5 to 5μ in diameter. This fungus has been

[1] "Mycology and Plant Pathology," p. 147.

found to produce suppurative inflammation of the external and middle portion of the human ear. It is also a cause of cork disease, so often imparting a disagreeable taste to bottled beverages.

Order 4.—**Tuberales,** the truffles. Fungi whose septate mycelium is often connected with the roots of trees forming the structure known as *mycorrhiza*. Several species of the genus *Tuber* growing in woods of France, Germany and Italy produce tuberous subterranean bodies called Truffles, which are highly prized as a table delicacy by the inhabitants of these countries.

Order 5.—**Helvellales,** the saddle fungi. Fleshy fungi entirely saprophytic, living attached to leaf mold or growing in humus soil or, in a few cases, on decaying wood. The fleshy fruiting bodies (ascocarps) are divided into stalk (*stipe*) and cap (*pileus*) portions. The external surface of the cap is covered with a layer of asci and paraphyses which together constitute the ascigeral layer. To this group belong the Morels and the Earth Tongues.

One of the Morels, *Morchella esculenta*, is frequently found in fire-swept woods. Its fruiting body consists of a hollow, externally ridged stipe, bearing upon its summit a fleshy pileus whose outer surface is honeycombed with ridges and depressions. The depressions are covered with an ascigeral layer composed of asci and paraphyses. This species is edible. (See Fig. 240.)

Order 6.—**Pyrenomycetales,** the mildews and black fungi, common as superficial parasites on various parts of plants. To the black fungi division of this order the Ergot fungus, *Claviceps purpurea*, belongs.

Life History of Claviceps Purpurea.—Through the agency of winds or insects the spores (ascospores or conidia) of this organism are brought to the young ovaries of the rye (*Secale cereale*). They germinate into long filaments called hyphæ, which, becoming entangled to form a *mycelium*, spread over the ovary, enter it superficially, secrete a ferment, and cause decomposition of its tissue and the resultant formation of a yellow, mucous substance called honeydew, which surrounds chains of moniliform reproductive bodies known as conidia. The honey dew attracts certain insects which disseminate the disease to other heads of grain.

The mycelial threads penetrate deeper and deeper into the ovary and soon form a dense tissue which gradually consumes the entire

FIG. 241.—*A*, *Balansia claviceps* on ear of *Paspalum; B–L*, *Claviceps purpurea; E*, sclerotium; *C*, sclerotium with *Sphacelia; D*, cross-section of sphacelial layer; *E*, sprouting sclerotium; *F*, head of stroma from sclerotium; *G*, section of same; *H*, section of perithecium; *J*, ascus; *K*, germinating ascospore; *C*, conidiospores produced on mycelium. (*See Die natürlichen Pflanzenfamilien* I, 1, p. 371.)

substance of the ovary and hardens into a purple, somewhat curved body called a *sclerotium*, or official ergot—the resting stage of the fungus, *Claviceps*.

The ergot falls to the ground and in the following spring sprouts into several, long stalked, globular heads called *stromata* or *ascocarps*. Each (fruiting) head or ascocarp has imbedded in its surface numerous flask-shaped invaginations called *perithecia*, from the bases of which several sacs or *asci* develop from the ends of hyphæ. Within each ascus are developed eight filiform spores (*ascospores*) which, when the ascus ruptures, are discharged and are carried by the wind to other fields of grain, there to begin over a new life cycle.

The Basidiomycetes or Basidia Fungi

This large class of fungi, including the smuts, rusts, mushrooms, gill and tooth fungi, etc., is characterized by the occurrence of a basidium in the life history. A *basidium* is the swollen end of a hypha consisting of one or more cells and giving rise to branches called sterigmata, each of which cuts off at its tip a spore, called a *basidiospore*. In addition to the basidiospores, some forms also produce one or more other types of spores. All of the members have a mycelium composed of septated hyphæ.

The Lower Basidiomycetes

This group comprises the smuts and rusts which are parasites living within the bodies of seed plants.

Order 1.—Ustilaginales, the smuts. Destructive parasites which attack the flowers of various cereals, occasionally other parts of these plants. Example: *Ustilago Maydis*, the corn smut. The basidiospores in this group are borne on a three- to five-celled basidium called a *promycelium*.

Ustilago Maydis (Ustilago Zeæ) (Corn Smut).—Corn smut is a destructive parasite which for a long time was supposed to be confined to the Indian Corn, but which now is known to occur on Mexican Grass. It is the only smut useful in medicine. The mycelium of the fungus extends through all parts of the infected organ of the host through the intercellular-air-spaces, sending short

absorbing branches into its cells. In due course of time, it produces large tumor-like swellings on the ears, tassels, husk, leaves, root and

FIG. 242.—Smut boil of *Ustilago zeæ* on ear of corn, developed from one infected kernel. (*After Jackson, F. S., Bull.* 83, *Del. Coll. Agric. Exper. Stat., December*, 1908.)

stem. Each swelling is at first made up of masses of hyphæ, the whole being covered with a tightly appressed membrane which has

a whitish appearance like German silver. Later the cells of the hyphæ lay down walls becoming divided into smaller cells, each of which becomes rounded off as a spore. This spore is known as a *chlamydospore* or *brand spore*. The spores are at first a dark olive-green, but on maturity are dark brown. They are sub-spherical and show prominent but tiny spines. These spores fall to the ground

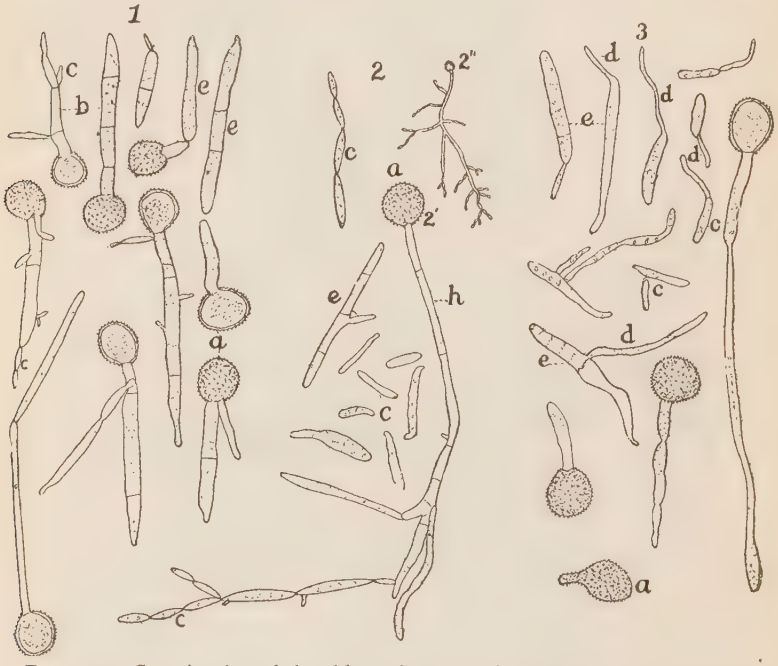

FIG. 243.—Germination of the chlamydospores of corn smut (*Ustilago zeæ*); 1, Various stages in germination from corn 3 days after being placed in water; 2, spores germinated in contact with air; 3, several days after spores were placed in ½₀ per cent. acetic acid, formation of infection threads. *a*, Spores; *b*, promycelia; *c*, basidiospores; *d*, infection threads; *e*, detached pieces of mycelia. (*After Bull. 57, Univ. Ill. Agric. Exper. Stat., March*, 1900.)

and pass the winter. In the spring each germinates into a three- to five-celled filament called a *promycelium*, from the cells of which *basidiospores* arise. The basidiospore, upon coming in contact with young growing tissue of or a wound upon the host plant, starts a new infection and develops a mycelium which penetrates the infected organ.

Order 2.—Uredinales, the rusts. Obligate parasites possessing a septated, branched mycelium which ramifies through the intercellular-air-spaces of the host and sends haustoria into the cell cavities. The different stages of their life cycle are either restricted to one host or distributed between two or more hosts. An outline of the life history of the wheat rust will give an idea of the peculiarities of the group.

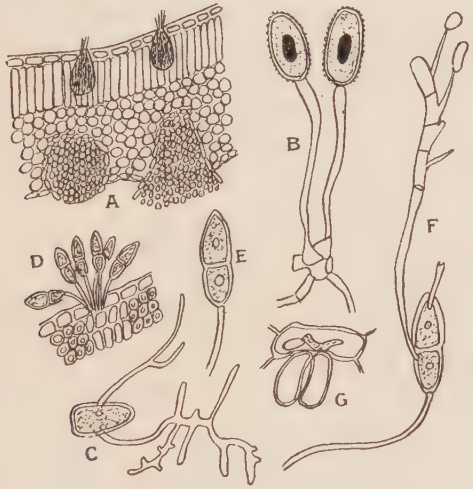

FIG. 244.—Spore forms of wheat rust, *Puccinia graminis*. *A*, Section through barberry leaf showing pycnia (spermagonia) on upper surface and æcia on lower; *B*, two urediniospores; *C*, germinating urediniospore; *D*, teliosorus showing several teliospores; *E*, single two-celled teliospore; *F*, germinating teliospore with four-celled basidium and two basidiospores; *G*, basidiospore growing on barberry leaf. (*Harshberger, adapted from deBary.*)

The Wheat Rust (Puccinia Graminis).—If we examine the wheat plant just before harvest we will find on the stems and leaves some rust-red lines. The presence of the mycelium of the fungus in the intercellular spaces of the host does not kill the host directly or appear to stunt its growth, but the effect of the parasite on the host is seen when the grains mature. The grains are small and mushy, due to the fact that the nutrition of the host had been disturbed and the formation of starch in the grains inhibited. The

mycelium is localized and gives rise underneath the epidermis to rounded egg-shaped spores attached to it by short pedicels. The spores are produced in such numbers that the space beneath is too confined. As the long epidermal cells of grasses run longitudinally, the pressure of the spore masses from within causes the epidermis to crack and its edges become turned back. Through the resultant cleft the *summer spores* or *uredospores* (uriediniospores) are thrust out. These uredospores are orange-brown in color and covered with minute spines. The mass of them has been called a *uredinium*. These spores are detached from the pedicels and blown by the wind to healthy plants. After summer is over and dry weather comes on, an examination of stubble in the field (blades of grass and stems of wheat left carelessly), shows that these rust-red lines are replaced by brownish-black spores called *teleutospores* (teliospores). A mass of these is known as a telium.

The summer stage on wheat is known as Uredo linearis.

The autumn stage on wheat is known as Puccinia graminis.

The teleutospores are two-celled and have thick walls and persistent pedicels. They remain attached to the stubble until the following spring and then either one or both cells composing them produce an outgrowth known as a *promycelium* (nothing but a basidium divided transversely into four cells). Each cell of the basidium is capable of producing a branch, at the tip of which a *basidiospore* is formed. These basidiospores are blown to the Barberry (*Berberis*) and infect the leaves of this plant. The mycelium runs in the intercellular-air-spaces and causes the appearance of a number of small depressions on the upper side of the leaf. These in section are a rich chocolate brown and known as *spermagonia*. In the center of a spermagonium are produced hyphæ, which project out to its orifice and obstrict off minute spores called *spermacia*. On the opposite side of the leaf cup-shaped depressions are formed, each with a limiting membrane (*peridium*). Within the cup-shaped depression thousands of spores are formed in chains closely packed together. These are the *æcidiospores* (*æciospores*). The cluster cup is called an *Æcidium* (Æcium). These æciospores are conveyed to wheat and cause infection, thus completing the life cycle. It has been observed that in America the uredospores

or summer spores may winter over and infect healthy plants, so that the Barberry phase is completely eliminated from the life cycle.

Order 3.—Auriculariales.—The so-called "ear fungi" which occur on the bark of many plants, on wooden fences, etc., as auriculate growths which when young are jelly-like and brilliantly colored, when old, hard, grayish and considerably wrinkled. The ear-like fruiting body is known as the *sporophore*. Its internal surface is lined with a *hymenium* or fruiting membrane consisting of numerous four-celled basidia, each of which cuts off at its tip a basidiospore. A common example of this group is the Jew's ear fungus.

Order 4.—Tremellales.—Saprophytes which live on decaying wood as moist, soft, quivering, gelatinous growths becoming later dry and horny.

The Higher Basidiomycetes

Mostly fleshy forms characterized by one-celled basidia with generally four, occasionally six, eight or two sterigmata, each of which cuts off a basidiospore at its tip.

Division a.—Hymenomycetes

(Hymenium or spore-bearing surface exposed)

This division of higher basidiomycete fungi comprises the following orders: Dacromycetales, Exobasidiales, Thelephorales, Clavariales and Agaricales.

Order 1.—Dacromycetales.—This order includes the "weeping fungi." One of the most common is *Dacromyces deliquescens* which occurs as a gelatinous body of bright red color on dead wood. The basidiospores are formed during a wet period and the fungus swells up in the water forming a slimy mass. In addition to basidiospores the mycelium may break up into oidiospores, if the wet period is prolonged. In consisting of slimy gelatinous masses the "weeping fungi" approach the *Tremellaceæ* but are distinguished from them in the basidium being undivided in the former and divided in the latter.

Order 2.—Exobasidiales.—This group is found growing parasitically on shrubs especially those of the heath family. The mycelium

lives in the tissues of the stems, leaves, sepals and petals and produces spongy, fleshy, yellowish or brownish galls which are popularly called "Azalea apples." The galls are edible. They are covered with a hymenium.

Order 3.—**Thelephorales.** These possess fruit-bodies appearing on tree trunks as flattened leathery or crust-like or bracket-like outgrowths often overlapping each other. Example: *Corticium.*

FIG. 245.—Coral-like fruit-bodies of *Clavaria flava.* (*Harshberger, from Photo by W. H. Walmsley.*)

Order 4.—**Clavariales,** the coral or fairy club fungi. Fleshy coral or club-shaped forms, all of which are saprophytes found in woods growing in bunches out of leaf mold. They are all edible and of a white, yellow or some other brilliant color. (See Fig. 245.)

Order 5.—**Agaricales,** the mushroom or toadstool alliance. Alike with the other members of the Basidiomycetes, the plant body consists of the mycelium, ramifying through the substratum, but the part which rises above the surface (the *sporophore* or fruiting body)

is in most cases differentiated into a stalk-like body called a *stipe* bearing upon its summit a cap or *pileus*, the latter having special surfaces for the *hymenium*.

Family I.—Hydnaceæ, or tooth fungi. This group is characterized by the hymenium being placed over purplish, spiny or long finger-like projections of the pileus. Many of the species of the genus *Hydnum* are edible.

FIG. 246.—*Boletus felleus* in three stages of development. (*After Patterson, Flora W.* and *Charles, Vera K., Bull.* 175, *U. S. Dept. Agric., pl. xxxi, Apr.* 29, 1915.)

Family II.—Polyporaceæ, or pore fungi. The sporophores or fruiting bodies of these fungi are various. They may be entirely supinate with pores or shallow depressions on their upper surfaces (*Merulius*), or mushroom-like (*Boletus*), or of the nature of woody or corky (*Fomes*) or fleshy (*Fistulina*) brackets. In all cases the hymenium or basidial layer lines the inner surface of tubes which open on the exterior as pores.

The sporophore or fruit body of *Polyporus officinalis*, when deprived of its outer rind and dried, constitutes the official N.F. drug **Agaricus.** This species grows abundantly on various species of pines, spruces and larches.

Family III.—Agaricaceæ, the gill family, in which the hymenium covers blade-like plates of the pileus, called *gills*, generally occurring on the under surface of the same. Examples: *Agaricus campestris*,

FIG. 247.—Meadow mushroom (*Agaricus campestris* L.). *A*, view showing under side of pileus; *g*, gills; *a*, annulus, or remains of the veil attached to the stipe; *B*, side view; *s*, stipe; *a*, annulus; *p*, margin of pileus, showing at intervals the remains of the veil. (*Gager, after W. A. Murrill.*)

the common edible mushroom of fields; *Amanita muscaria* and *Amanita phalloides*, both of which are poisonous.

Agaricus Campestris (Common Mushroom).—This plant is an edible gill fungus which grows in open, grassy fields during late summer and early autumn. It is never found in the forest or on trees or fallen trunks, seldom in the mountains. The cultivated form grows in specially constructed houses made of boards. A corridor runs through these houses so that the mushroom beds can be easily reached. In the growth of mushrooms tons of horse manure are used. This is covered with loamy soil 1½ inches thick. The whole mass is compacted together. Into the resultant beds is introduced

English-grown spawn, which comes in flat brick-shaped masses (horse manure through which mycelium has grown). Pieces of these "bricks" are put in the horse manure bed only after the heat has first disappeared. The beds are then watered well and in a short time the *sporophores* or fruiting bodies of the fungus spring up.

The mycelium or vegetative body of *Agaricus* which develops in the soil from spores (basidiospores) is white and thready. On this mycelium develop little white buttons, first about the size of a pin head, becoming later pea size and then assuming a pear-shaped form. At this stage the sporophore consists of a cylindrical solid stipe or

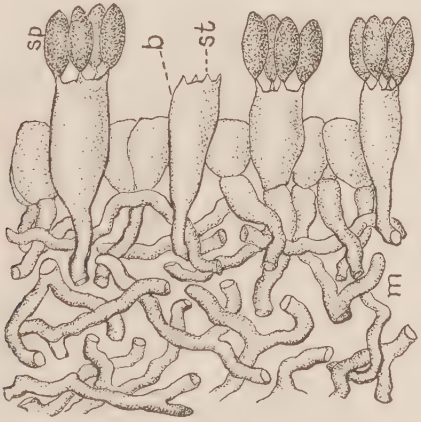

FIG. 248.—Fruiting surface (hymenium) of a mushroom (*Agaricus*). *m*, hyphæ of the trama and sub-hymenium; *b*, basidium; *st*, sterigma; *sp*, spores. Diagrammatic. (*Gager.*)

stalk and a pileus or cap. The border of the pileus is joined to the stipe by means of a "*partial veil.*" Within this veil is found a circular cavity, into which the *gills* grow. At first the stipe grows faster than the rest of the fruiting body. The pileus expands transversely and the gills keep pace. After a while the veil ruptures, leaving a portion attached to the stipe. This constitutes the *annulus* or *ring* (true annulus). The hyphæ in the pileus form the *Tela contexta.* If we make a section through a gill, the hyphæ are seen to run longitudinally. The central part is called the *trama;* next and out-

side trama is the *sub-hymenium;* next, *hymenium,* consisting of *basidia* (hence a basidial layer). Each basidium bears two or four little points known as sterigmata. Each sterigma bears a purplish-brown basidiospore. The basidiospores falling to the ground germinate into hyphæ and these become interlaced to form a mycelium.

In the wild mushroom the gills are at first pink, in cultivated, fawn-colored. Ultimately in the wild form the gills turn brownish.

FIG. 249.—Deadly amanita (*Amanita muscaria*) showing volva at base of stipe and frill-like stipe ring. (*After Chestnut, V. K., Bull.* 175, *U. S. Dept. Agric., pl. i, Apr.* 29, 1915.)

The spores are purplish-brown. The color of the stipe and upper surface of the pileus varies from whitish to drab color.

The Amanitas (Poisonous Fungi).—*Amanita muscaria* and *Amanita phalloides*, commonly known as the "fly agaric" and the "deadly agaric," respectively, are very poisonous forms. *Amanita muscaria* is common in coniferous forests, although it may be found in cultivated soil and along roadsides. It occurs singly or in patches. Its chief poisonous constituent is muscarine for which atropine is an antidote·

An emetic should first be given. *Amanita phalloides* is found in woods and borders of fields and occurs singly and not in groups.

Each of these have fruiting bodies (sporophores), which begin at the surface of the ground as a button similar to that of the edible mushroom. This enlarges and assumes a dumbbell shape. The whole bottom is covered by an outer veil, known as the *velum univer-*

FIG. 250.—The deadly amanita, *Amanita phalloides*. Note the cup at the base of the stipe. (*Gager, from photo by E. M. Kittredge.*)

sale, which encloses the pileus, gills and stipe. As the stipe lengthens more rapidly than the pileus, the upper part of the veil is stretched and finally breaks in its middle portion. The lower part remains as a cup, out of which the stipe grows. The upper part is carried up as shreds adhering to the margin of the pileus. The lower part is called the *volva* or death cup. The annulus present is a false annulus,

for it represents a peeling down of the upper part of the stipe. Both have chalk-white gills, a white stipe, and white spores.

The pileus of *Amanita muscaria* varies from yellow, to orange, orange-red to blood-red. The surface is smooth, with prominent warty scales. Its stipe is at first stuffed, later hollow.

The pileus of *Amanita phalloides* varies from pure white to dull yellow to olive or umber. It does not possess the warty scales found in the *Amanita muscaria,* but occasionally has a few membranous patches. Its stipe is generally smooth, solid below but hollow upwards.

FIG. 251.—A colony of Puff Balls, *Lycoperdon,* growing saprophytically upon a portion of a rotten log. (*Photograph by author.*)

Amanita phalloides is the most poisonous of all species of toadstools. Its chief poisonous constituents are the glucoside amanita-hemolysin and the toxin called amanita-toxin. Amanitahemolysin is a blood laking principle. No antidote is known which will neutralize the deadly effects of this fungus.

Division b.—Gasteromycetes

(Hymenium inclosed)

Order 1.—Lycoperdales, or puff ball alliance. This order includes a number of interesting parasites and saprophytes, the most common of which are the earth stars belonging to the genus *Geaster* and the

puff balls, the most common form being *Lycoperdon*. In these, the fruiting sporophore consists for the most part of a shell-like covering called the *peridium*, composed of an outer layer or *exoperidium* and an inner layer or *endoperidium*. The peridium in the unripe condition of the sporophore covers a mass of soft cellular tissue called the *gleba*. Upon the ripening of this mass, the interior is seen to be divided into many-branched compartments that are separated from each other by walls made up of branched hyphæ. These walls are lined with a hymenium composed of many basidia, each of which constricts off usually four basidiospores. The earth stars differ from the puff balls in possessing an outer wall or exoperidium which splits in star-shaped fashion.

FIG. 252.—Mature stinkhorn, *Dictyophora duplicata*. (*Harshberger, from photo. by W. H. Walmsley.*)

Order 2.—Nidulariales, the nest fungi. A group of Gasteromycetes whose sporophores are crucible- or crater-like. These arise from a subterranean mycelium and show an outer and inner peridial layer. The outer peridium is roughened at its base. The inner peridium is leathery and may or may not be continued over the top. When mature the crucible-like body shows black seed-like bodies inside which resemble eggs in a bird's nest. Each one of these is connected with the inner peridium by a cord which resembles the umbilical cord of an animal. These inner bodies are called *peridiola* (sing. *peridiolum*). Each peridiolum consists of a hard glistening outer layer and a spongy inner layer surrounding a cavity into which basidia and basidiospores project. These fungi are found in stiff clayey soil.

Order 3.—**Phallales,** the carrion or stink-horn fungi. This group consists of highly and characteristically colored forms which, when mature, emit most vile and penetrating odors. The fruiting body, in each instance, begins as an egg-shaped structure which starts its growth from a widely spread under-ground mycelium of chalky-white color. As the "eggs" enlarge they push above the surface of the ground. The central portion, elongating, then breaks through the outer or peridial portion, which remains as a cup or volva at the base of the mature fruit body. Upon the summit of the central stalk rests the cup-like, many-chambered gleba. The basidiospores are imbedded in a greenish fetid slime formed by a mucilaginous disintegration of the substance of the hymenium. This fetid green material is attractive to carrion flies which visit the plants and remove the material with its embedded spores. The latter will not germinate until after passing through the alimentary canal of these flies.

The Fungi Imperfecti

An assemblage of varied forms, the life histories of most of which are imperfectly understood. In this group are included numerous parasites which produce diseases in crop plants.

CHAPTER XIX

THE LICHENS

Lichens are variously colored, usually dry and leathery plants, consisting of symbioses of algæ and fungi. In each case the fungus derives its food from materials manufactured by the alga and in return extracts water from the substratum and shares it with the alga. The association is therefore mutually beneficial. While Blue-green and Protococcus forms of Green Algæ and Ascomycete

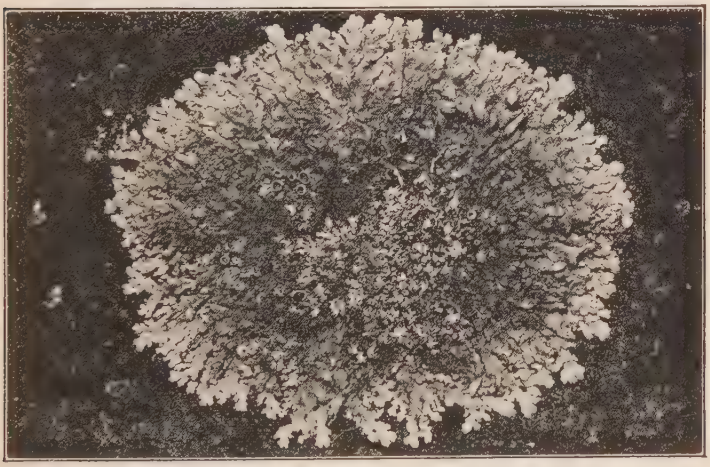

FIG. 253.—A foliaceous lichen, *Physica stellaris* (L.) Nyb., growing on a rock. The cup-shaped structures are the fruiting bodies (apothecia). At the left are seen two very young plants. (*Gager.*)

Fungi are for the most part concerned in lichen formation, in some instances Basidiomycete Fungi are also involved with the algæ. Thus we have two distinct classes of Lichens depending upon the type of fungus associated with the alga, viz.: *Asco-lichens* and *Basidio-lichens.*

Lichens are found on the bark of trees, on rocks, logs, old fences, etc.

According to the manner of growth of the thallus and nature of attachment to the substratum, three different sub-groups of lichens may be distinguished, viz.: (1) Foliaceous, where the thallus is flat, leathery and leaf-like and attached to the substratum at different points. To this group belong *Physica*, *Sticta* and *Parmelia*. (2) Crustaceous, where the thallus closely adheres to rocks and bark of trees. To this group belong *Graphis* and *Pertusaria*. (3) Fruticose, where the thallus is upright and branching. To the last group belong *Cetraria islandica*, species of *Cladonia*, and *Usnea*.

FIG. 254.—*Cetraria islandica*, or Iceland Moss, a medicinal lichen. (*Sayre.*)

Structure.—The body of a typical lichen shows a differentiation into the following regions:

(1) A *tegumentary layer* of several rows of hyphal cells.

(2) An *upper cortex* of densely arranged hyphal cells.

(3) An *algal layer* containing green algal cells, often called *gonidia*.

(4) A *medullary layer* of loosely interwoven fungal hyphæ, with large air-spaces. This is usually the broadest layer and sometimes also contains algal cells.

(5) A *lower cortex* of hyphal cells, less dense than the upper cortex. From the surface cells of this layer rhizoids are developed which absorb water and nutrient salts from the substratum.

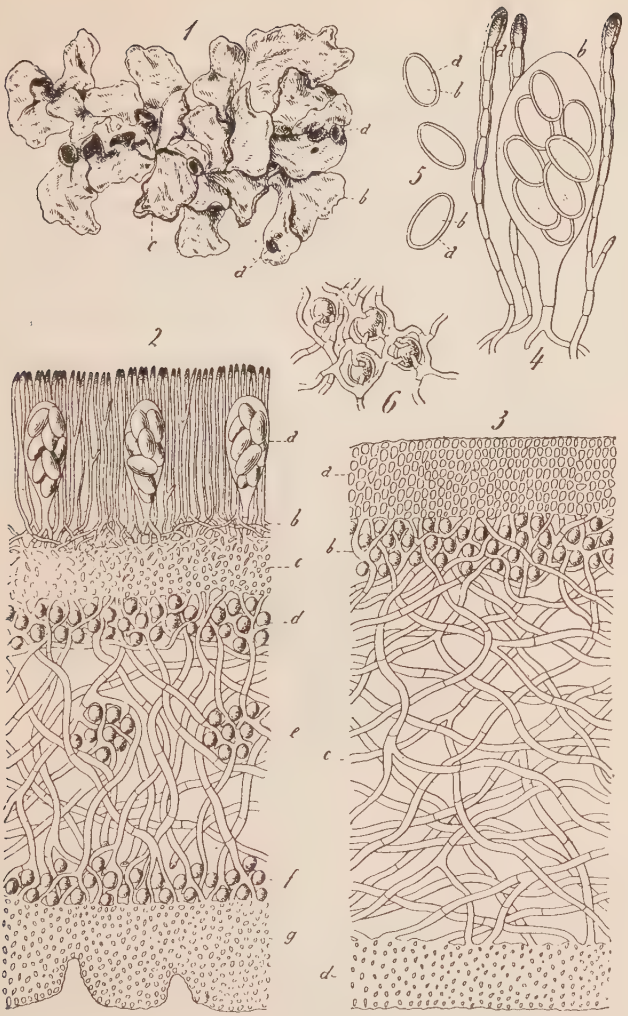

FIG. 255.—A lichen, *Parmelia perlata* (L.) Ach. 1. Plant, slightly reduced in size; *a*, apothecia; *b*, lobe of thallus; *c*, soredial patches. The soredia are vegetative reproductive bodies composed of both algal and fungal elements, and therefore able to reproduce the lichen; the ascospores, alone, cannot do this. 2. Longitudinal section of apothecium; *a*, thecium; *b* and *c*, the two layers of the hypothecium; *d*, upper algal layer; *e*, colonies of algae distributed through the medullary layer; *f*, lower algal layer; *g*, lower cortical layer. 3. Cross-section of vegetative portion of thallus. 4. Paraphyses (sterile fungal filaments), and spore-sac (ascus), containing ascospores. 5. Ascospores. 6. Algal cells, surrounded by fungal hyphae with haustoria (absorbing branches). (*Gager.*)

Reproduction.—Lichens reproduce either by producing spores or by detaching scale-like portions of their bodies. In the Asco-lichens (which make up the majority) either saucer-shaped structures called *apothecia* (sing. *apothecium*) occur on the upper surface or dark-colored, spherical structures called *perithecia* somewhat embedded in the upper surface, arise. In either type of structure *asci* and sterile hyphæ (*paraphyses*) arise. Each ascus usually contains eight spores. The spores upon maturity are liberated, each germinating in the presence of moisture into a hypha. The hypha, upon

FIG. 256.—*Rocella tinctoria*, a dye-yielding lichen. (*From Strasburger after Wiesner.*)

coming into contact with an alga cell, grows around it to form a lichen.

Scales or *soredia* are found on many lichens. These consist of a network of hyphæ enclosing algal cells. By becoming detached from the parent plant, they develop new lichens and so constitute a means of vegetative propagation.

Uses.—To the pharmacist and chemist lichens are chiefly of interest because of the coloring principles which they contain. Species of *Lecanora* and *Rocella tinctoria* yield, when subjected to fermentation, the dyes orcein and litmus. Litmus is one of the best indicators in volumetric analysis. Cudbear, a purplish-red powder,

used extensively for coloring pharmaceutical preparations in the form of tincture, is prepared by treating species of *Rocella*, *Lecanora* or other lichens with ammonia water. Other lichens, such as *Cetraria islandica*, various species of *Parmelia*, *Usnea* and *Alectoria*, have been used in medicine because of demulcent principles which they contain.

One of the most conspicuous lichens in northern latitudes is the Reindeer Moss (*Cladonia rangiferina*). It is a slender, branched, fruticose form which grows to the height of about a foot and bears its brownish apothecia at the ends of branches. In Artic regions it occurs in dense patches covering large areas and forms the only kind of fodder available in many sections for reindeer and caribou.

Another lichen, *Lecanora esculenta*, is thought to represent the source of Scriptural Manna. It has been employed as a food in periods of famine by the natives of southwestern Asia.

CHAPTER XX

THE BRYOPHYTES

This interesting group, comprising the second division of the Vegetable Kingdom, is represented by the liverworts and the mosses. These plants show a beginning of definite alternation of generations, *i.e.*, *gametophyte* (sexual phase) alternating with *sporophyte* (asexual phase of development) in their life history, the two phases being combined in one plant. The sporophyte is attached to the gametophyte throughout its existence, being parasitic upon it. Of the two phases, the gametophyte is always the larger and more conspicuous structure. The female sexual cell is always lodged in an *archegonium* (a multicellular female sexual organ).

HEPATICÆ OR LIVERWORTS

The liverworts are a class of aquatic or terrestrial plants occurring in tropical and temperate regions. While most of them live in moist land situations, some are found submerged or floating in water, some are *epiphytic*, and others occur in localities where long dry seasons prevail. The body of a liverwort either consists of (1) a small, flat, dichotomously branching thalloid body showing differentiation into a green upper or dorsal region and a nearly colorless under or ventral part, as in *Riccia* or *Marchantia* or (2) of a branching stem which bears two rows of dorsal leaves containing chloroplasts and one row of pale ventral leaves, as in *Porella* and other higher liverworts. Reproduction is by fertilization or by vegetative multiplication. Some species develop both kinds of sexual organs (antheridia and archegonia) on the same gametophyte and so are *monœcious*, while others develop antheridia on one gametophyte and archegonia on another gametophyte and are therefore *diœcious*.

There are three orders of liverworts, viz.:

Order 1.—**Marchantiales,** including *Marchantia* and *Riccia.*

Order 2.—**Jungermanniales,** the leafy liverworts, including *Porella.*

Order 3.—**Anthocerotales,** having the most complex sporophyte generations among liverworts, including *Anthoceros* and *Megaceros.*

FIG. 257.—A liverwort (*Lunularia*). Below, portions of the thalloid body, showing the lunar-shaped cupules, with brood-buds, or gemmæ. Above a single gemma, greatly magnified. (*Gager.*)

MARCHANTIA (A TYPICAL LIVERWORT)

One of the most common and widely distributed liverworts is *Marchantia polymorpha.* It occurs in dense patches in the moist surface of soil in flower pots of greenhouses and on the damp rocks and humous soil of woodlands.

Gametophyte Generation.—The gametophyte or sexual plant consists of a dichotomously branched *thalloid body* with a distinct midrib. With a hand lens it will be noted that its green upper surface exhibits numerous pale green lines which divide it into small rhomboidal-shaped areas. In the center of each of these is a

pore which leads into an air-chamber within the body. Its lower surface is nearly colorless and exhibits *rhizoids* and delicate *scales*.

A cross section of the thalloid body, when examined microscopically, will disclose an upper epidermis of epidermal cells containing

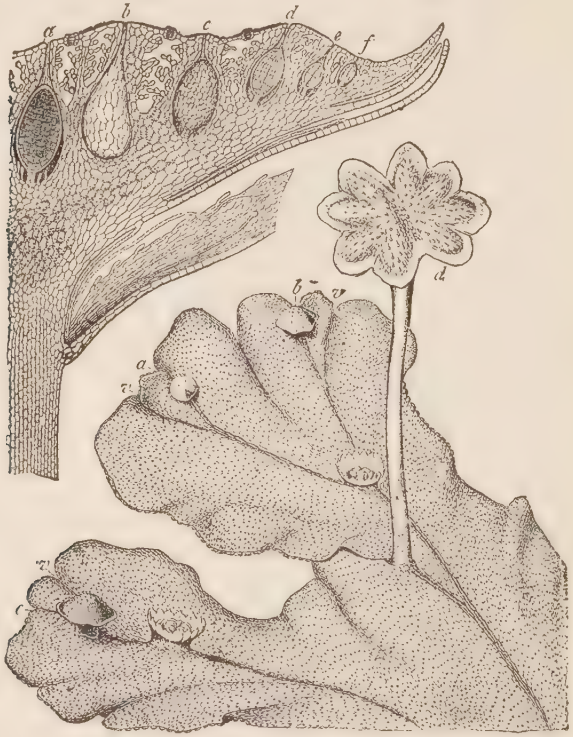

FIG. 258.—*Marchantia polymorpha.* Male gametophyte. Lower figure: Thalloid body with cupules containing gemmæ and male receptacles (antheridiophores) in various stages of development, *a, b, c, d.* Upper figure: antheridia in depressions of upper surface of disk of male receptacle, in successive stages of development, *f, e, d, c, a. b*, depressions with the antheridium taken out. (*From Small after Kny.*)

chloroplasts and showing *stomata*, each stoma surrounded by four vertical rows of cells. Directly beneath this is a row of *air-chambers* separated by partitions. In each air-chamber branched rows of densely *chlorophylloid cells* grow upward from the cells which con-

stitute its floor. These do most of the work of photosynthesis. Below the air-chambers are several rows of clear parenchyma cells containing only a few *chloroplasts*. From the lower surface of these are to be noted outgrowths as slender rhizoids and scales.

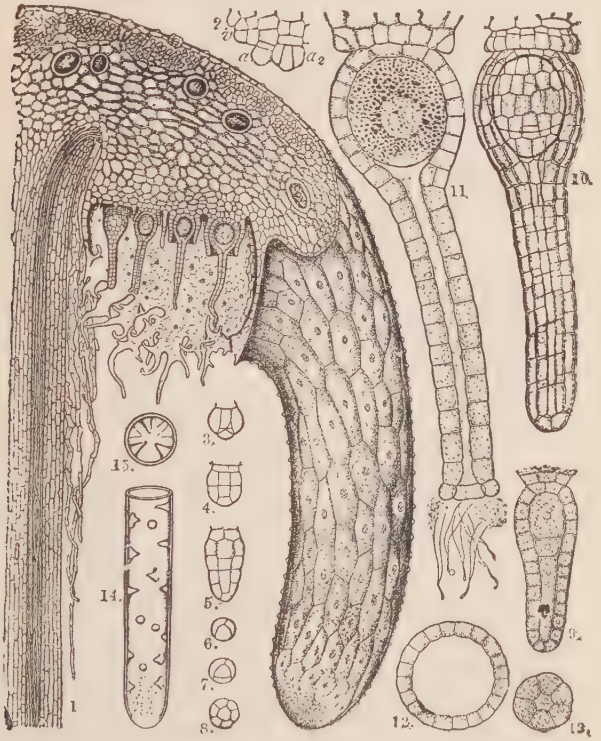

FIG. 259.—*Marchantia polymorpha*. 1, Vertical section of one lobe of the disk of the archegonial receptacle, showing archegonia on lower surface, the group being surrounded by a laciniate perichaetium. $2a$, $2a_2$, 3, 4, 5, 9, 10, Successive stages in the development of the archegonium. 6, 7, 8, Transverse sections of the same. 11, Mature archegonium with antherozoids attracted to mouth. 12, Transverse section of venter of mature archegonium. 13, Transverse section of neck of same, showing six cells. 14. Tuberculate rhizoid. 15, Transverse section of same. (*From Small after Kny.*)

Some of the gametophytes will show cup-like structures on their upper surface. These are called *cupules*. They contain special

buds called *gemmæ* which, upon being detached, may give rise directly to a new gametophyte. This is the vegetative method of reproduction.

Marchantia is *diœcious* for it produces two kinds of gametophytes, one bearing antheridia (male) and another archegonia (female).

FIG. 260.—*Marchantia polymorpha.* 1. Thalloid body of Female Gametophyte with archegonial receptacles (archegoniophores) in successive stages of development, a_1, a_2, *b*, *c*, *d*, *e*, *f*. 2, 3, Upper and under views of archegoniophore when the sporophytes are ripe. 4, 5, Stages in the development of the sporophyte. 6, Young sporophyte enclosed by a perigynium. 7, Mature sporophyte shedding spores. 8, Elater and spores. 9, Surface view of cells from wall of capsule. (*From Small after Kny.*)

There is no way of distinguishing one from the other until stalked structures or *receptacles* arise from the upper surface of the gametophyte.

The *antheridial receptacle* consists of an erect stalk surmounted by a disk with an eight lobed edge. Embedded in numerous separate cavities of the upper region of the disk are the *antheridia.*

The *archegonial receptacles* consist of a stalk surmounted by an umbrella-shaped disk with about nine somewhat pendant rays. On the lower surface of the disk the *archegonia* arise as flask-shaped structures which hang downward.

The *antheridia* are somewhat oval and consist of a wall of *sterile cells* surrounding a mass of *sperm mother cells.* The latter give rise to the *sperms* or *antherozoids* which are biciliate.

The *archegonia* are flask-shaped structures, each of which posseses a basal bulbous part called the *venter* and an elongated tubular part termed the *neck.* The flask has an outer layer of *sterile cells* and a central axial row of cells which from the base of the venter upward are the *egg cell*, *ventral canal cell* and *neck canal cells.* As the archegonium matures, the horizontal walls of the canal cells are dissolved by an enzyme and the contents of the cells are transformed into a mucilaginous mass. During wet weather the upper portion of the wall of the mature antheridium bursts open and the biciliate sperms are liberated in a mucilaginous mass. Attracted by the substances then issuing from the mouths of the archegonia, they swim toward them and usually a number pass down the neck of the canal of each archegonium and gather around the egg. One of them unites with the egg fertilizing it and forming an *oospore.* The act of fertilization concludes the gametophyte generation.

The Sporophyte.—The oospore enlarges and then divides to form a spherical mass of cells which in time become differentiated to form a sporophyte or asexual plant which consists of (1) a basal *foot* which attaches the sporophyte to the base of the archegonium and absorbs nutrient substances in solution from it, (2) a short *stalk* which gradually lengthens and (3) a *capsule* composed of an outer layer of sterile cells enclosing *spores* and slender, elongated cells called *elaters.*

Upon the rupture of the wall of the capsule the spores are discharged, being aided in their dispersal by the elaters, found among the spores which, being hygroscopic, and with spirally thickened walls, bend and twist giving force to the process of spore distribu-

tion. Each spore, upon absorbing water, may develop into a gametophyte.

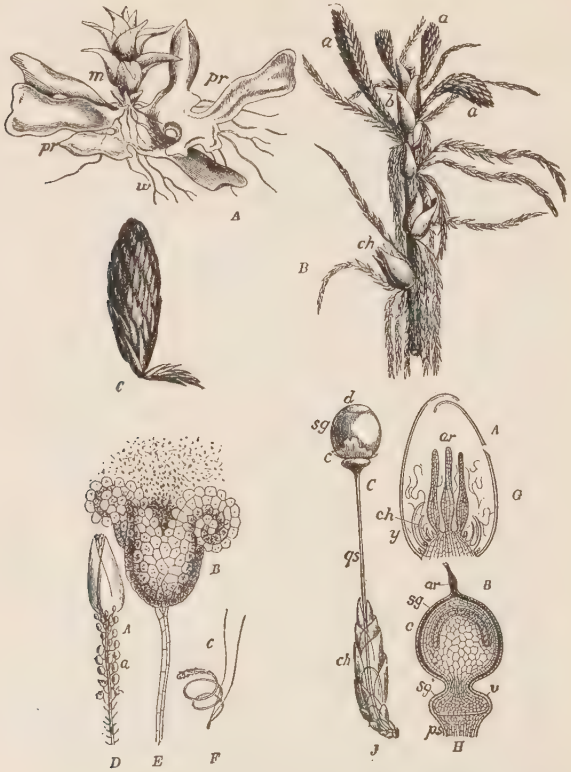

FIG. 261.—*Sphagnum acutifolium*, Ehrb. *A*, prothallus (*pr*), with a young leafy branch just developing from it; *B*, portion of a leafy plant; *a*, male cones; *ch*, female branches; *C*, male branch or cone, enlarged, with a portion of the vegetative branch adhering to its base; *D*, the same, with a portion of the leaves removed so as to disclose the antheridia; *E*, antheridium discharging spores; *F*, a single sperm; *G*, longitudinal section of a female branch, showing the archegonia (*ar*); *H*, longitudinal section through a sporogonium; sg^1, the foot; *ps*, pseudopodium; *c*, calyptra; *sg*, sporogonium, with dome of sporogenous tissue; *ar*, old neck of the archegonium; *J*. *Sphagnum squarrosum* Pers.; *d*, operculum; *c*, remains of calyptra; *qs*, mature pseudopodium; *ch*, perichætium. (*Gager, from Schimper.*)

Alternation of Generations.—In the life history of Marchantia there are two distinct generations. The gametophytes bear the

sex organs in which gametes (sperm and egg) are produced. The sperm unites with the egg forming an oospore. The oospore develops into a sporophyte which forms spores. Each spore may develop into a gametophyte.

male gametophyte—sperm
female gametophyte—egg
oospore—sporophyte—
spores
male gametophyte
female gametophyte

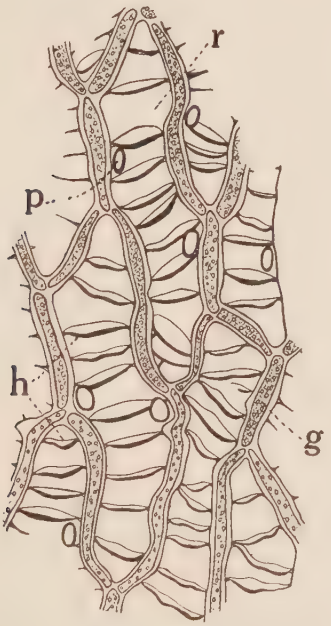

FIG. 262.—Surface view of portion of a leaf of *Sphagnum palustre* showing reservoir cell (*r*); transverse bands that prevent cells from collapsing (*h*); pores in reservoir cells (*p*); and green cells containing chlorophyll (*g*).

MUSCI OR MOSSES

Plants found on the ground, on rocks, trees and in running water. Their life histories consist of two generations, gametophyte and sporophyte similar to the liverworts but differ from liverworts, generally, by the ever-present differentiation of the gametophyte

body into distinct stem and simple leaves, and the formation of the sexual organs at the end of an axis of a shoot. They are either *monœcious*, when both kinds of sexual organs are borne on the same plant, or *diœcious*, in which case the antheridia and archegonia arise on different plants.

Order 1.—**Sphagnales,** or Bog Mosses, including the single genus, *Sphagnum*. Pale mossses of swampy habit whose upper extremities repeat their growth periodically while their lower portions die away gradually and form peat, hence their frequent name of Peat Mosses. Peat in a dry state is used as fuel.

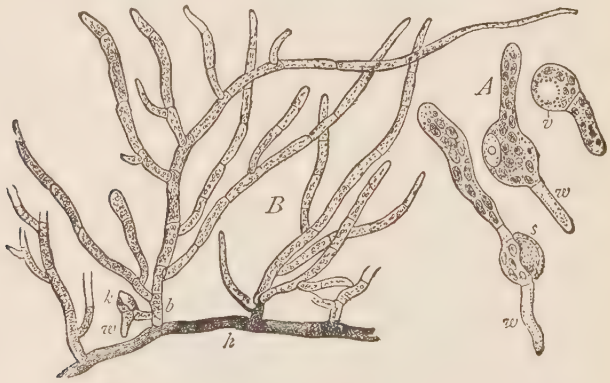

FIG. 263.—Protonema of a Moss. *A*, Early stages of germinating spores: *v*, vacuole; *w*, rhizoid; *s*, spore wall or exosporium. *B*, Developed protonema about three weeks after germination; *h*, primary filament; *k*, bud and *w*, rhizoid. The bud develops into a gametophytic plant. (*After Sachs from Small.*)

A number of species of *Sphagnum* have been recently employed in surgery as absorbents in place of gauze. For this purpose they must be thoroughly cleaned and sterilized.

The power which bog mosses have to absorb water depends on the presence of large empty cells, the walls of which have pores and are supported by ring-like thickenings. Between these empty cells are elongated narrow cells containing chloroplasts.

Order 2.—**Andreæales,** including the single genus Andreæa, of xerophytic habit, occurring on siliceous rock.

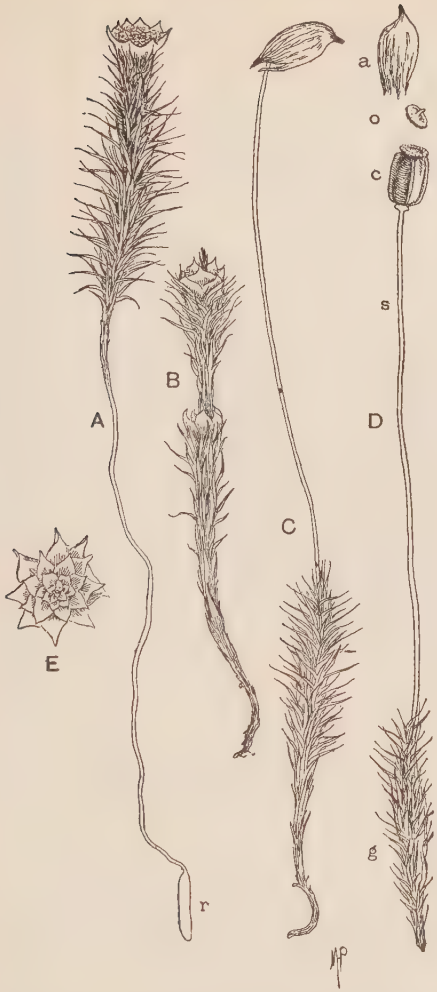

FIG. 264.—Hair-cap moss (*Polytrichum commune*). *A*, male plant; *B*, same, proliferating; *C*, female plant, bearing sporogonium; *D*, same; *g*, gametophyte; *s*, seta; *c*, capsule; *o*, operculum; *a*, calpytra; *E*, top view of male plant. (*Gager.*)

Order 3.—Bryales, or true mosses, comprising the most highly evolved type of bryophytes. Examples: *Polytrichum, Funaria, Hypnum,* and *Mnium.*

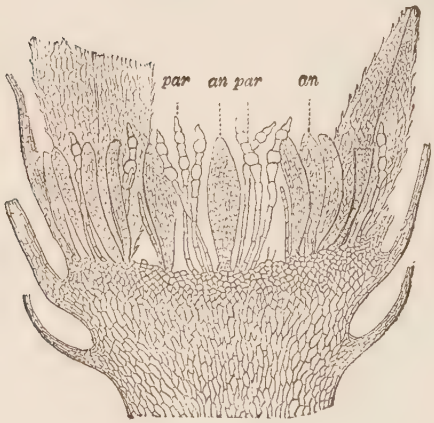

FIG. 265.

FIG. 266.

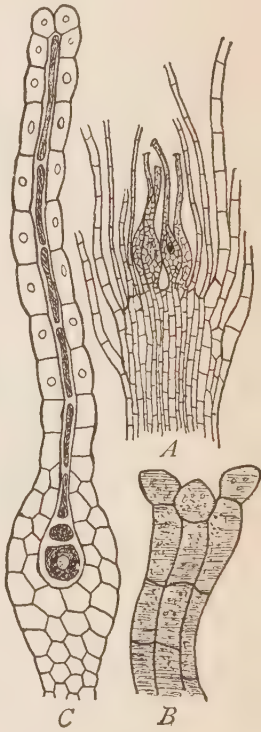

FIG. 267.

FIG. 265.—Vertical section through summit of male gametophyte of a Moss. *Mnium hornum* (× 40) *an,* Antheridia; *par,* Paraphyses.

FIG. 266.—*A,* Antherozoid of Moss (× 1,200); *B,* Antherozoid of ferm (× 700).

FIG. 267.—*Funaria.*—*A,* Apex of female gametophyte with archegonia. *B,* Neck of archegonium, showing mode of separation of the cap cells. *C,* Immature archegonium. (*From Small after Sachs.*)

Life History of Polytrichum Commune (A Typical True Moss).—*Polytrichum commune* is quite common in woods, forming a carpet-like covering on the ground beneath tall tree canopies. It is diœcious, the plants being of two kinds, male and female.

Beginning with a spore which has fallen to the damp soil, we note its beginning of growth (germination) as a green filamentous body composed of chloroplast-containing cells arranged end to end. This is called a *protonema*. This protonema soon becomes branched, giving rise to hair-like outgrowths from its lower portion called *rhizoids* and *lateral buds* above these which grow into leafy stems bearing rhizoids at their bases and which are commonly known as

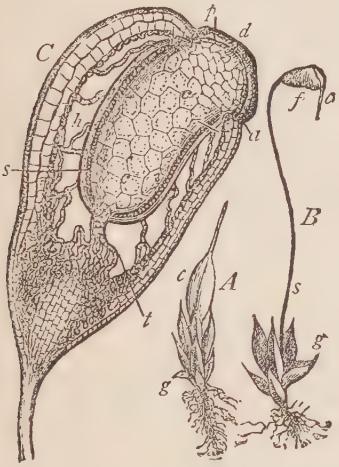

FIG. 268.

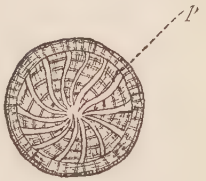

FIG. 269.

FIG. 268.—*Funaria hygrometrica*. *A*, Young sporophyte (*c*) attached to gametophyte (*g*). *B*, Adult sporophyte with seta (*s*) and capsule (*f*); gametophyte (*g*), part of which forms the calyptra (*o*). *C*, Vertical section of capsule (× 80). Operculum (*d*); Peristome (*p*); Annulus (*a*); Air-space with trabeculæ or filaments (*t*); Sporogenous layer (*s*). (*From Small, after Prantl.*)

FIG. 269.—Surface view of peristome of Funaria, after removal of operculum. *p*, peristome tooth. (*After Small.*)

"moss plants." At the tips of some of these leafy stems *antheridia* (male sexual organs) are formed while on others *archegonia* (female sexual organs) are formed. The leafy tip of the male plant can readily be distinguished from that of the female plant by its cup-like shape and orange color. These organs are surrounded at the tips by delicate hairy processes called *paraphyses* as well as leaves for protection. The antheridia bear the *antherozoids*, the archegonia, the eggs or *ova*, as in the liverworts. When an abund-

ance of moisture is present, the antherozoids are liberated from the antheridia, swim through the water to an archegonium and descend the neck canal, one fertilizing the egg by uniting with it. This completes the sexual or gametophyte generation. The fertilized egg now undergoes division until an elongated stalk, bearing upon its summit a capsule, is finally produced, this entire structure being known as the *sporogonium*. The base of the stalk remains imbedded in the basal portion of the archegonium, at the tip of the leafy stalk, and forms a *foot* or absorbing process. In growing upward the sporogonium ruptures the neck of the archegonium and carries it upward as the covering of the capsule, or *calyptra*. The calyptra

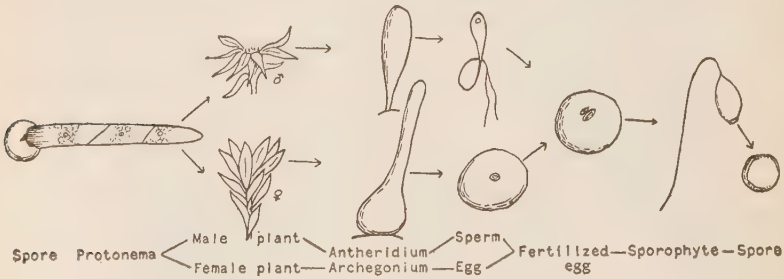

FIG. 270.—Diagram of the life history of a moss. (*After Atwood.*)

is thrown off before the spores are matured within the capsule. The upper part of the capsule becomes converted into a lid or *operculum* at the margin of which an *annulus* or ring of thick-walled cells forms. Attached to the annulus by their bases are a number of long triangular teeth called collectively the *peristome*. The cells of the annulus are hygroscopic and expand at maturity, throwing off the lid. The peristome teeth are very hygroscopic. During rainy weather or when the atmosphere is very humid they bend inward preventing the escape of the spores. During dry weather they straighten out and in this process lift out some of the spores and allow others to sift out from the cavity of the capsule. This completes the asexual or sporophyte generation. The spores falling to the damp soil germinate into protonemata, thus completing the life cycle in which is seen an alteration of generations, the two phases, gametophyte alternating with sporophyte.

CHAPTER XXI

THE PTERIDOPHYTES

The Pteridophytes constitute the third great division of the Plant Kingdom. They are the most highly developed cryptograms, showing not only a distinct alternation of generations in their life histories, but more advanced structural development. They differ from the Bryophytes in presenting independent, leafy, vascular, root-bearing sporophytes.

The Pteridophyta are grouped into three classes, viz.:

1. Lycopodineæ or Club Mosses.
2. Equisetineæ or Horsetails.
3. Filicineæ or Ferns.

THE CLUB MOSSES

Small perennial, vascular, dichotomously branched, trailing, evergreen herbs with stems thickly covered with awl-shaped leaves. The earliest forms of vascular plants differing from ferns in being comparatively simple in structure, of small size, and in having sessile leaves which usually possess a single vein. Except in a few instances the sporangia are borne on leaves, crowded together and forming cones or spikes at the ends of erect branches. The spores found within the sporangia are either alike or unlike in size, hence the plants are either *homosporous* or *heterosporous*.

Family I.—Lycopodiaceæ, including the single genus *Lycopodium* with widely distributed species. The group is homosporous. The spores of *Lycopodium clavatum* are official.

Life History of Lycopodium Clavatum.—This species of club-moss thrives in temperate and sub-tropical forests of both hemispheres and yields a light-yellow, mobile powder consisting of spores. This powder is of value in pharmacy to prevent the adhering of suppositories, pills, etc., and in medicine as a protective to tender surfaces.

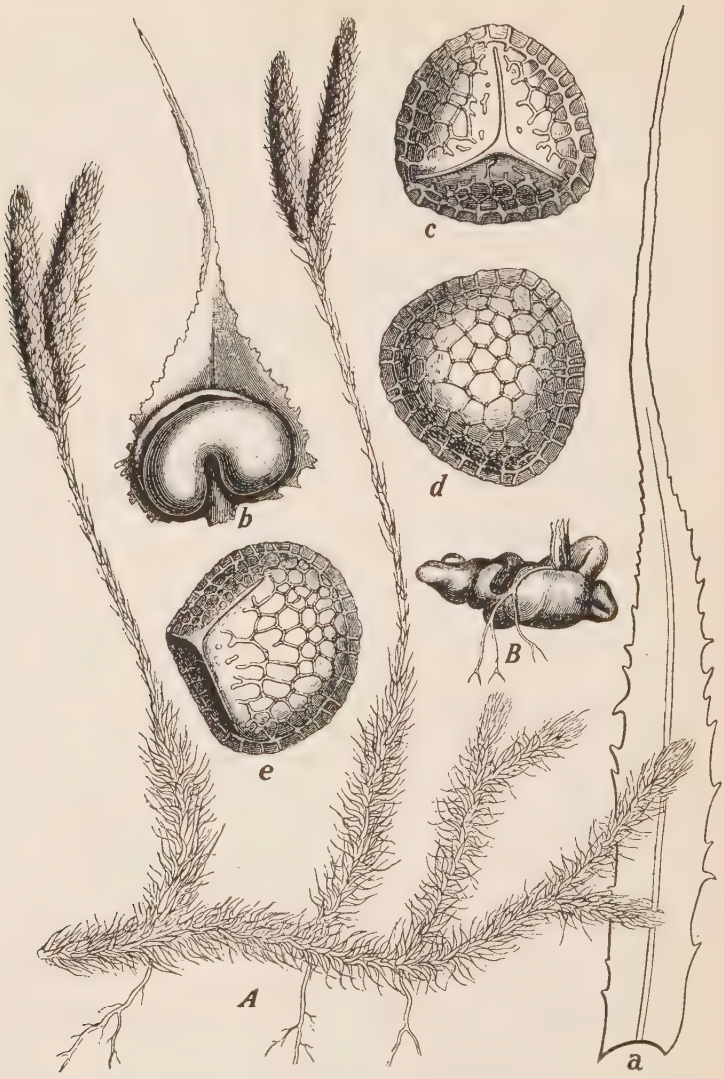

FIG. 271.—*Lycopodium clavatum* L. *A*, portion of sporophyte plant showing habit (natural size); *a*, foliage leaf; *b*, sporophyll, with kidney-shaped sporangium at base (magnified); *c*, *d*, *e*, spores viewed from different aspects (× 580); *B*, prothallus of another species. (*After Luerssen.*)

When examined under the microscope the spores appear tetrahedral with one convex and three plane surfaces. The outer wall (*exosporium*) of each is reticulated, showing meshes that are surrounded by polygonal ridges with straight sides. In nature, these spores, falling

FIG. 272.—*Selaginella Martensii*. *a*, vegetative branch; *b*, portion of the stem, bearing cones (*x*); *c*, longitudinal section of a cone, showing microsporangia (*mic. sp.*) in the axils of microsporophylls, and megasporangia in the axils of megasporophylls; *d*, microsporangium with microsporophyll; *e*, microspores; *f*, portion of wall of sporangium, greatly magnified; *g*, megaspore; *h*, microsporangium opened, and most of the microspores scattered; *i*, megasporangium, with megasporophyll; *k*, same, opened, showing the four megaspores. (*Gager.*)

out of the ripe spore cases, germinate on moist soil, each producing a fleshy *prothallus* which is submerged in its lower portion and exposed above ground in its upper part. This structure has *antheridia* and *archegonia* imbedded in its upper end and shows elongations of its epidermal cells as *rhizoids* in its tuberous, sunken, lower part which

absorb nutriment from the soil. The mature antheridia burst open during wet weather and liberate biciliate *antherozoids*. Each mature archegonium produces an *ovum* in its basal cavity. Antherozoids (*sperms*) swim to the mouth of the archegonium, pass down its canal and gather about the ovum.

One of these fertilizes the ovum forming an *oöspore*. The oöspore begins to divide and ere long develops into an embryo which soon becomes differentiated into *foot* and *shoot* regions. The foot absorbs nourishment from the prothallus, for a short time, until the first root commences to function. The *shoot* elongates carrying the first leaves above the soil and giving rise to the first root or *radicle* at its base. Through continued growth and differentiation a mature *sporophyte* is developed which consists of a creeping, prostrate, dichotomously branching stem covered with crowded, light green, linear, awl-shaped, and bristle-tipped leaves and bearing several ascending fertile branches which terminate in one or two *spikes*. Each of these spikes consists of a slender *axis* bearing numerous more or less deltoid, bristle-tipped *scales*, each one having a kidney-shaped *sporangium* at the base of its upper surface containing numerous *spores*.

Family II.—Selaginellaceæ (Little Club Mosses), including the single genus *Selaginella* with species for the greater part tropical. Plants similar in habit to the *Lycopodiaceæ* but producing microspores and megaspores, hence showing heterospory.

Family III.—Isoetaceæ (Quillworts) including the single genus *Isoetes* whose species are plants with short and tuberous stems giving rise to a tuft of branching roots below and a thick rosette of long, stiff, awl-shaped leaves above. They produce microspores and megaspores and so show heterospory.

THE HORSETAILS

The Equisetineæ, commonly known as the Horsetails or Scouring Rushes, are perennial herbs with hollow, cylindrical, jointed and fluted stems, sheath-like whorls of united leaves and terminal cone-like fructifications. Their bodies contain large amounts of silicon, hence the name scouring rushes. Only 25 species exist today and all of these belong to the genus *Equisetum*. These are believed to

represent degenerate descendants of tree-like Horsetails, fossils of which have been found in coal-bearing rocks of the Carboniferous period.

In some species of Equisetum the fruiting cone is borne on the ordinary aerial stem, in others on a special stem of slightly different form. The spores are provided with ribbon-like appendages called *elaters*, which, being hygroscopic, coil and uncoil with increase or decrease in the amount of moisture present, thus aiding in the entanglement of the spores into small masses, and so preventing isolation, an advantage on account of the dioecious character of the prothallia which they originate.

LIFE HISTORY OF EQUISETUM ARVENSE, A HORSETAIL

Equisetum arvense, a frequently occurring species along railroad embankments but also in fields, may be taken as a type form of the group. Like other horsetails its life history involves an alternation of sporophyte and gametophyte generations of which the sporophyte is the more conspicuous.

The sporophyte consists of a subterranean, horizontally-branched food-storing *rhizome* (main axis) bearing on its lower surface water- and mineral nutrient absorbing-roots and on its upper surface 2 kinds of jointed, hollow shoots—*sterile* and *fertile*. The *sterile shoots* are green and bear whorls of shortened, green branches from their upper nodes and scale-like leaves from their lower nodes. Theirs is the work of manufacturing food for the plant. The *fertile shoots* are nearly or completely devoid of chlorophyll and bear whorls of scale-like leaves at their nodes and terminate in a *cone*. The central stalk of this cone is a prolongation of the shoot axis and bears numerous whorls of *sporophylls*. Each sporophyll consists of a short stalk and a disk; the latter is arranged in peltate fashion on the end of the stalk and bears a number of *sporangia* on its lower surface. Within these sporangia are produced numerous *spores* which are liberated upon the ripening of the sporangia. While alike as to size, some of them give rise upon germination to *male prothallia*, others to *female prothallia*. These prothallia represent the sexual or gametophyte plants. The male prothallia produce *antheridia*

along the margins or tips of their lobes in which, when mature, numerous many-ciliated *antherozoids* are found. The female prothallia produce flask-shaped *archegonia* on the prothallial cushion each of which contains an *egg*. Both kinds of prothallia bear absorp-

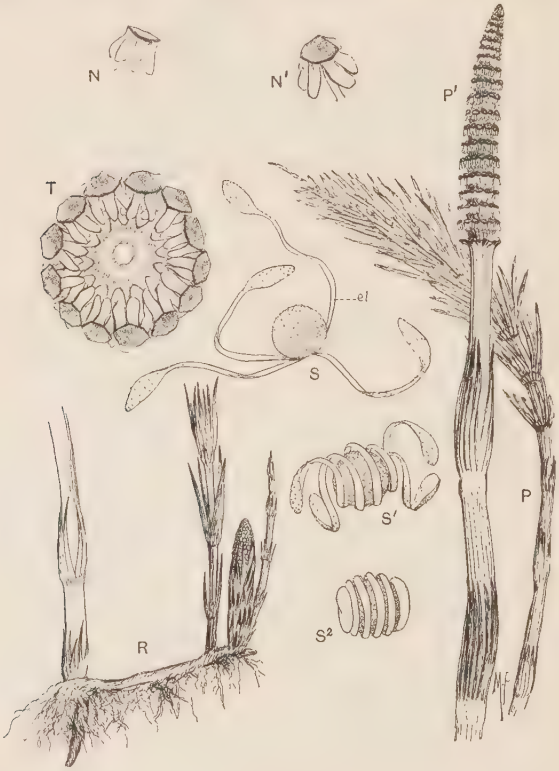

FIG. 273.—*Equisetum arvense*. *P*, sterile branch; P^1, fertile branch with strobilus, or cone; *R*, rhizome (underground); *T*, cross-section of cone, showing insertion of sporophylls in a whorl; *N*, N^1, sporophylls with pendant sporangia; *S*, S^1, S^2, spores with coiled elaters (*el*). (*Gager.*)

tive *rhizoids* on their lower surface. The antherozoids, liberated from the antheridia of male prothallia, swim to the archegonia of neighboring female prothallia, enter their mouths, pass down their neck canals and gather about the eggs. In each instance the best

adapted one fertilizes the egg. The fertilized egg (*oöspore*) develops into an embryo which through continued growth becomes a mature sporophyte plant.

THE FERNS

The ferns, constituting the class *Filicineæ*, represent the largest group of the vascular cryptogams.

Ferns occur in a variety of situations in tropical and temperate countries. Most of them prefer damp, shady places. Some grow in forests and fields, others in the crevices of rocks, still others in water. In the tropics, some ferns become tree-like in form, possessing long erect trunks bearing at their summit a crown of compound leaves called *fronds*. In temperate regions, the land ferns have underground stems or *rhizomes* from which fronds arise.

The main axis of the majority of the typical land-growing ferns is a creeping underground stem or *rhizome* which at its various nodes bears *rootlets* below and *fronds* above. These fronds are highly developed, each being provided with a petiole-like portion called a *stipe* which is extended into a *lamina* usually showing a forked venation. Some ferns possess laminæ which are lobed, each lobe being called a *pinna*. If a pinna be further divided, its divisions are called *pinnules*. In some ferns the pinnules are further subdivided into *secondary pinnules*, as in the "brake" or "bracken," *Pteris aquilina*. The unfolding of a frond is circinate and it increases in length by apical growth. On the under surface of the laminæ, pinnæ, or pinnules may be seen small brown patches each of which is called a *sorus*, and usually covered by a membrane called the *indusium*. Each sorus consists of a number of *sporangia* (spore cases) developed from epidermal cells. In some ferns the entire leaf becomes a spore-bearing organ (sporophyll). Most sporangia have a row of cells around the margin, the whole being called the *annulus*. Each cell of the annulus has a U-shaped, thickened cell wall. Water is present within these cells and when it evaporates it pulls the cell walls together, straightening the ring and tearing open the weak side. The annulus then recoils and hurls the spores out of the sporangium. Upon coming into contact with damp earth, each spore germinates, producing a green septate filament called a

FIG. 274.—*Dryopteris marginalis*, a fern whose rhizome and stipes constitute the drug, American Aspidium.

protonema. This later becomes a green heart-shaped body called a *prothallus*. It develops on its under surface *antheridia* or male organs and *archegonia* or female organs as well as numerous *rhizoids*. Within the antheridia are developed motile, many ciliated *sperms*, while *ova* are produced within the archegonia. The many ciliate sperms escape from the antheridia of one prothallus during a wet season and, moving through the water, are drawn by a chemotactic

FIG. 275.—Fern leaves, showing various degrees of subdivision or branching of the blade. *A, Phyllitis; B, Polypodium; C, Pteris; D, Adiantum.* (*From Gager.*)

influence to the archegonia of another prothallus, pass down the neck canals of these and fuse with the ova, fertilizing them. The fertilized egg or oöspore divides and redivides and soon becomes differentiated into a *stem*, *first leaf*, *root*, and *foot*. The foot obtains nourishment from the prothallus until the root grows into the soil, when it atrophies, and the sporophyte becomes independent. Unequal growth and division of labor continue until a highly differentiated sporophyte results, the mature "fern plant."

In some species of ferns as the Cinnamon Fern (*Osmunda cinnamomea*) and the Sensitive Fern (*Onoclea sensibilis*), two kinds of fronds are produced, *sterile fronds* which represent green foliage leaves and *fertile fronds* which contain little or no chlorophyll and bear clusters of sporangia.

ORDER 1.—FILICALES OR TRUE FERNS (HOMOSPOROUS)

Family *Polypodiaceæ.*—Sporangia with annulus vertical and incomplete. This family includes most of the more common ferns of temperate regions.

The rhizomes and stipes of *Dryopteris filix-mas* and *Dryopteris marginalis* are valuable in medicine. Those of the former species are

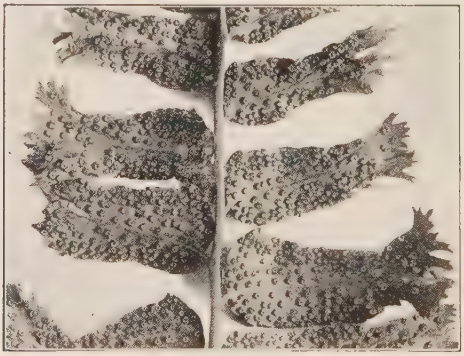

FIG. 276.—*Cyrtomium falcatum.* Under (dorsal) surface of a portion of a sporophyll, showing the numerous sori on the pinnæ. (*Gager.*)

official in the U.S.P. The fibro-vascular bundles of the stems and leaves of these and other ferns are concentric in type but differ from the concentric fibrovascular bundles of the stems and leaves of some monocotyledons in that xylem is innermost and phloem surrounds the xylem. For further details on fern structure see Chapter V.

ORDER 2.—HYDROPTERALES OR WATER FERNS (HETEROSPOROUS)

Family *Salviniaceæ.*—Floating ferns with broad floating leaves and submerged dissected leaves which bear fruit bodies called sporo-

carps containing microsporangia and megasporangia. The microsporangia contain microspores which give rise to male prothallia. The megasporangia contain megaspores which develop female prothallia. Examples: *Salvinia*, *Marsilea* or the Water Shamrock, and *Azolla*.

CHAPTER XXII

THE SPERMATOPHYTES

This is the highest evolved division of the vegetable kingdom. It includes all plants which produce real flowers and seeds. The older name for the group is Phanerogamia. The Spermatophytes are subdivided into two subdivisions based primarily upon whether

FIG. 277.—*Cycas revoluta*, a Cycad, showing terminal bud of foliage-leaves just opening. (*Gager.*)

their seeds are borne naked or enclosed within a seed vessel or pericarp.

Subdivision I. Gymnospermæ (Gymnosperms)—plants with naked seeds.

Subdivision II. Angiospermæ (Angiosperms)—plants with covered seeds.

THE GYMNOSPERMS

The Gymnosperms comprise an ancient and historic group of seed plants which were more numerous in the Triassic and Carboniferous periods than now. They differ from the Angiosperms in several

FIG. 278.—The White Pine (*Pinus strobus*).

respects, viz.: they bear naked ovules on the edges or flat surfaces of leaves called carpels, while Angiosperms bear covered ones; each megaspore produces within itself a bulky prothallus, in the upper portion of which originate one or more archegonia, while in Angio-

sperms no recognizable prothallus has been proven to exist; the stored food tissue within their seeds is prothallial tissue loaded with starch, etc., while that in Angiosperm seeds (endosperm) is developed from the endosperm nucleus; the mode of growth of their stems is

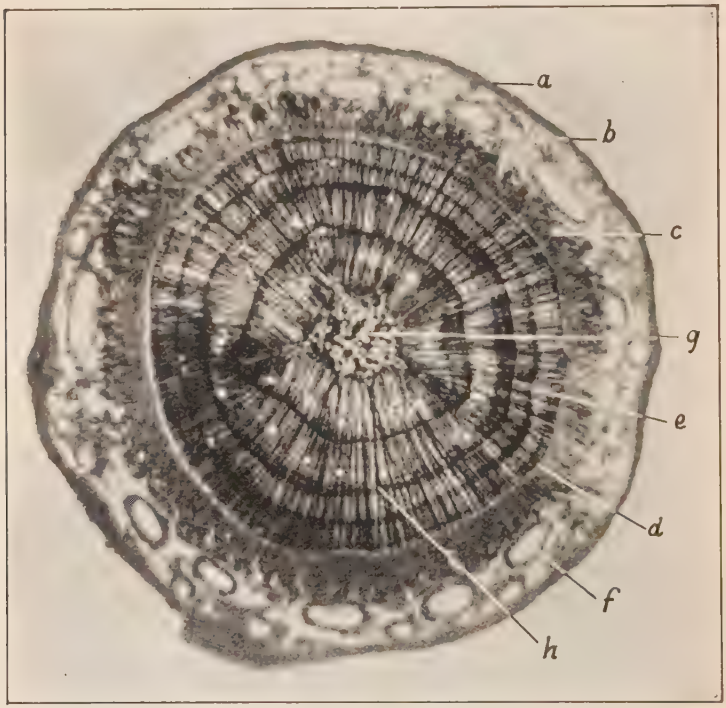

FIG. 279. Transverse section of white pine stem of four years' growth, showing cork (*a*), cortex (*b*), phloem (*c*), cambium (*d*), xylem (*e*), secretion reservoir (*f*), pith (*g*) and medullary-ray (*h*). (Photomicrograph.) × 16.

always indefinite while that of Angiosperms is either indefinite or definite.

The groups still extant are the Cycads or Fern Palms, the Gnetums, the Ephedras, the Ginkgos and the Conifers. Of these the Conifers comprising over 300 species are the most numerous. Many of them yield valuable products to pharmacy and the arts.

The Conifers include the pines, spruces, hemlocks, cedars, firs, redwoods, yews, arbor vitæ, chamæcyparis, and larches. All of their number are evergreen except the European larch, which drops its foliage upon the advent of winter.

LIFE HISTORY OF A GYMNOSPERM (PINUS STROBUS)

The White Pine frequently called the Weymouth Pine (*Pinus Strobus*), one of the principal timber trees of the Northern States

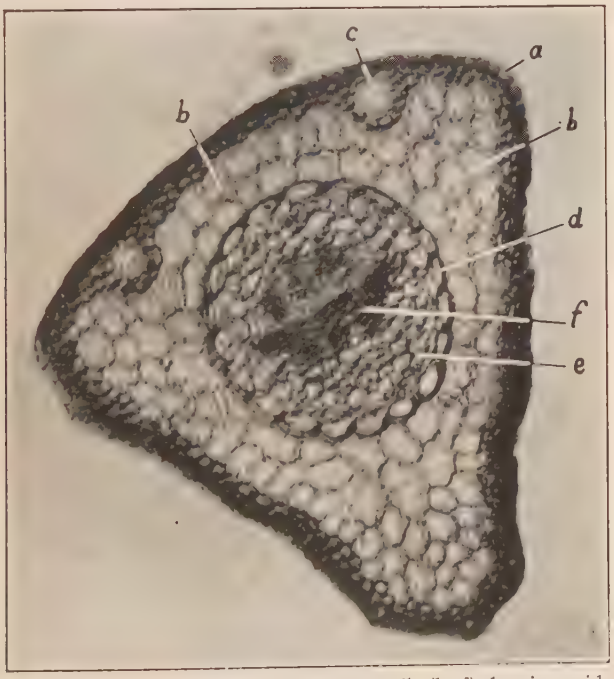

FIG. 280.—Transverse section of white pine needle (leaf) showing epidermis (*a*), infolded parenchyma cells of mesophyll (*b*, *b'*), oil reservoir (*c*), endodermis (*d*), clear cellular area (*e*) surrounding fibrovascular tissue in center (*f*). × 400.

and Canada, is also of value in pharmacy and medicine. The inner bark of its trunk and branches is used because of its valuable expectorant properties and is official in the National Formulary.

DESCRIPTION OF THE WHITE PINE TREE (MATURE SPOROPHYTE)

From an underground spreading root system there arises an erect aerial *trunk* or stem that extends from the ground to the apex of the tree, ending in a terminal bud. The trunk rarely exceeds 3 feet in diameter and 125 feet in height and is averagely 1½ to 3 feet in diameter and 50 to 90 feet high. At a varying distance above the soil, depending upon environal conditions as well as the age of plant,

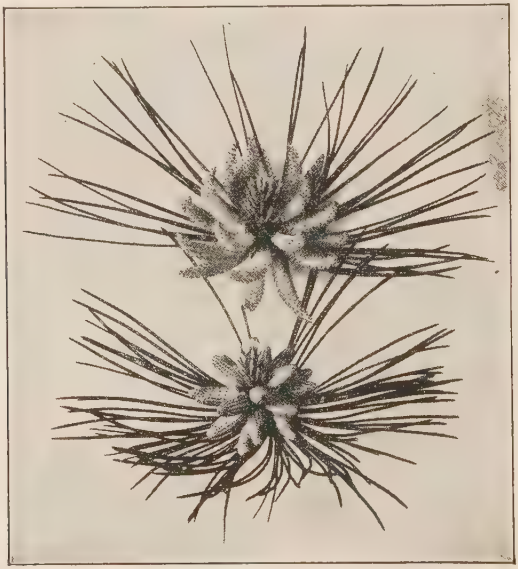

FIG. 281.—Staminate cones of the Austrian pine (*Pinus austriaca*). Below, before shedding pollen; above, after shedding. (*Gager.*)

whorls of lateral branches (three to seven in a whorl) are seen emanating from the trunk, in horizontal fashion, at various levels up to near the apex. These become, under conditions prevalent when the tree is grown in the open, gradually shorter until the summit is reached, giving to the *crown* or upper part of the tree the appearance of a pyramid. These branches give rise to other branches which agree with the lateral branches in bearing, commonly, only scale like leaves as well as in ending in terminal buds. Another kind of

branch, however, is found which is always shorter than the scale branches. This type of branch is called a "*spur shoot*" and arises from the former branches. The spur shoots bear the *needles* or *foliage leaves* which are light-green, when young, and bluish-green, soft, flexible, 2½ to 5 inches long, when mature. The "needles" occur in tufts (*fascicles*) of five, are triangular in cross-section, have

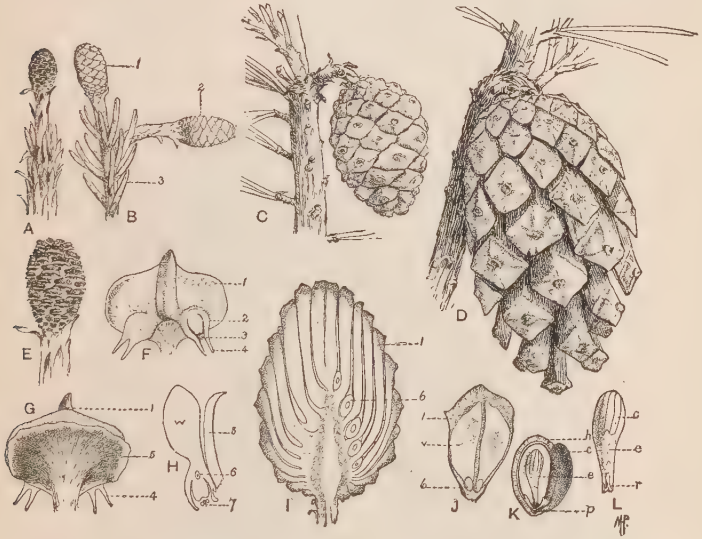

FIG. 282.—Scotch pine (*Pinus sylvestris*). *A-D*, stages in the development of the carpellate cone, and its carpotropic movements. *E*, very young carpellate cone much enlarged; *F*, ventral, *G*, dorsal views of a scale from *E*; 1, ovuliferous scale, 2, ovule (in longitudinal section); 3, pollen chamber and micropyle leading to the apex of the nucellus (megasporangium); 4, integument of the ovule; *G*, 1, tip of ovuliferous scale; 5, bract; 4, integument; *H*, longitudinal section at right angles to the surface of the ovuliferous scale (diagrammatic); 6, megaspore; 7, pollen chamber; *I*, longitudinal section of a mature cone; 6, ovule; *J*, scale from a mature cone; 6, seed; *w*, wing of seed; *K*, dissection of mature seed; *h*, hard seed coat; *c*, dry membraneous remains of the nucellus, here folded back to show the endosperm and embryo; *e*, embryo; *p*, remains of nucellus; *L*, embryo; *c*, cotyledons; *e*, hypocotyl; *r*, root-end. (*Gager.*)

finely *serrate* (*saw-toothed*) edges and are surrounded at the base by a deciduous sheath. These foliage leaves persist until the end of their second year, when they are shed with the spur shoot which bears them.

The white pine, like most of its allies among the Coniferæ, bears cones. These structures are of two kinds, viz.: staminate and carpellate. Both kinds are produced on the same tree.

Staminate Cones.—The yellow, ovate, staminate cones appear about May and are clustered at the base of the new growth of the current season. Each consists of a main axis (modified branch) which bears spirals of scales called *microsporophylls* or *stamens*. On the under surface of each scale are the spore-cases (*microsporangia*), which develop the *microspores* (*pollen grains*). Each pollen

Fig. 283.—Mature carpellate cones of white pine showing separated scales.

grain when mature consists of a central fertile cell and a pair of air-sacs or wings, one on either side of the fertile cell. The purpose of the latter is to give greater buoyancy in the air to the microspore.

Carpellate Cones.—The young carpellate cones appear in May or early June as pinkish-purple structures arranged in solitary fashion or in small groups, lateral along the new growth. Each terminates a lateral axillary branch. A carpellate cone is composed of a main

axis which bears spirals of scales, by some termed *megasporophylls* (*carpels*). Each scale is composed of an ovuliferous scale bearing two *ovules* or *megasori* and a bract. Each megasorus contains a *nucellus* or *megasporangium* which is surrounded by an integument, except at the apex where an opening, the micropyle, is evident. The micropyle is the gateway to the *pollen chamber* which lies below it. Within the nucellus occurs a *megaspore* or *embryo sac.*

DESCRIPTION OF THE GAMETOPHYTE GENERATION

The Gametophyte generation of the White Pine begins with the development of the male and female gametophytes and terminates with the fertilization of the egg.

The Male Gametophyte.—The male gametophyte commences to form in the mature pollen grain before the pollen is shed. A series of three nuclear divisions takes place which cut off two small prothallial cells (traces of one of which may be seen pushed up against the wall of the fertile cell of the pollen grain), a tube nucleus and a generative cell. At this stage the pollen is shed and some of it is carried by air currents to the carpellate cones where it sifts in between the ovule-bearing scales and accumulates at the scale bases. A number of the pollen grains are drawn close to the nucellus of the ovule by the drying up of the viscid fluid which fills the *pollen chamber.* In this fluid they germinate forming pollen tubes. The transfer of pollen grains from the pollen sac to the pollen chamber and consequent germination therein is called *pollination. The contents of a mature pollen-grain constitutes the male gametophyte.*

The Female Gametophyte.—If the embryo-sac be examined at about the time of pollination, it will be found to consist of a single cell containing a single nucleus surrounded by cytoplasm. Very shortly afterward, however, the nucleus divides repeatedly to form a large number of nuclei which are scattered throughout the cytoplasm. Each nucleus accumulates around itself a portion of the cytoplasm and ultimately cell walls are laid down and the entire embryo-sac contains *endosperm* (prothallial) tissue. Toward the micropylar end of the endosperm (*prothallus*) originate several archegonia.

Each archegonium consists of a much-reduced neck of four cells and an egg (*ovum*) which lies embedded in the prothallus which forms a narrow layer of cells around it called the *jacket*. *The contents of the mature embryo-sac constitutes the female gametophyte.*

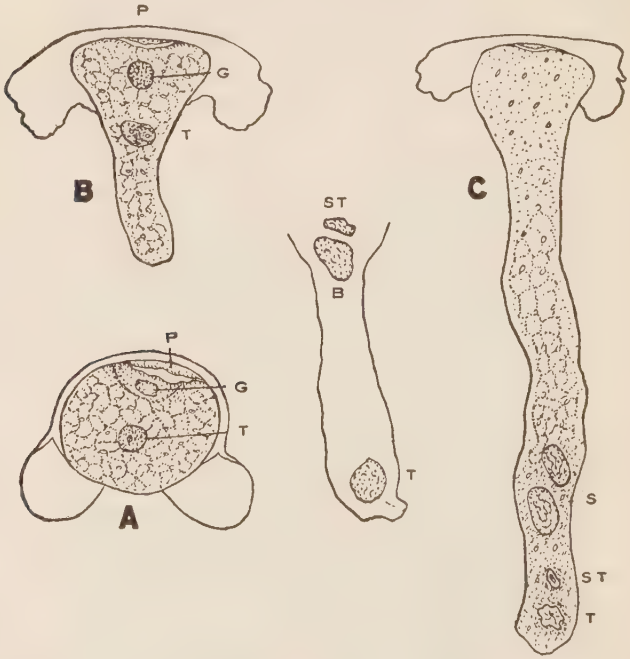

FIG. 284.—Pine Pollen and development of pollen tube. In *A* the pollen grain is shown containing prothallial cells (*p*). They have been cut off before the grain was shed. The tube nucleus (*T*) has been divided off from the generative nucleus (*G*).

In *B* the tube has been put forth and the tube nucleus has moved down into it. Between the stages represented in *B* and *C* the generative nucleus has divided to form a stalk nucleus (*ST*) and a body nucleus (*B*).

In *C* four nuclei are present in the pollen tube,—the tube nucleus (*T*), the stalk nucleus (*ST*), and the two sperm nuclei (*S*). The sperm nuclei have been produced by a division of the body cell, the latter having disappeared. (*After Atwood.*)

After pollination the carpellate cone gradually bends on its axis so as to ultimately reverse its position and hang downward.

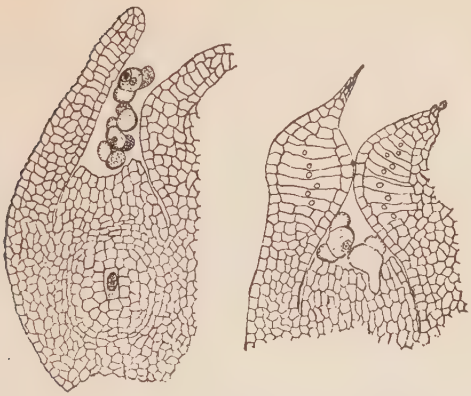

FIG. 285.—White pine (*Pinus Strobus*). At left, megasporangium with megaspore in the center; above, pollen grains in the micropyle and pollen chamber. At right, pollen grains beginning to germinate; the cells of the integument have enlarged and closed the micropyle. (*Gager, after Margaret C. Ferguson.*)

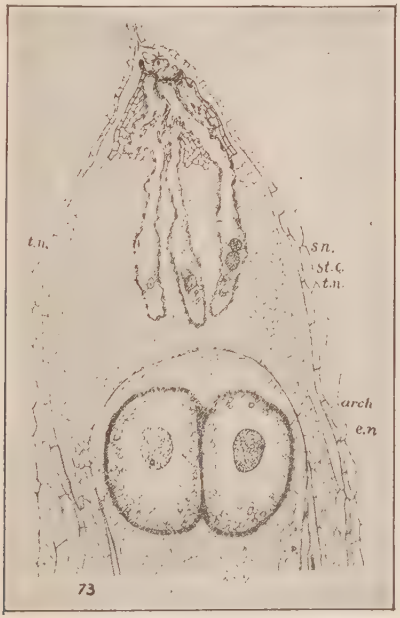

FIG. 286.—White pine (*Pinus Strobus*). Vertical section through the upper part of an ovule, shortly before fertilization. *s.n.*, sperm-nuceli; *st. c.*, stalk-cell; *t.n.* tube-nucleus; *arch*, archegonium; *e.n.*, egg-nucleus. (*Gager, after Margaret C. Ferguson.*)

Fertilization.—About a year after pollination the pollen tubes, lying within the pollen chamber show signs of renewed activity. The tube nucleus passes to the tip of the tube. The generative-cell divides to form a body and a stalk-cell which pass into the tube. The body-cell later forms two sperm nuclei. While these changes are taking place the tube is penetrating the nucellus and growing toward the embryo sac with its contained female gametophyte. It finally enters it, passing between the neck-cells of the archegonium.

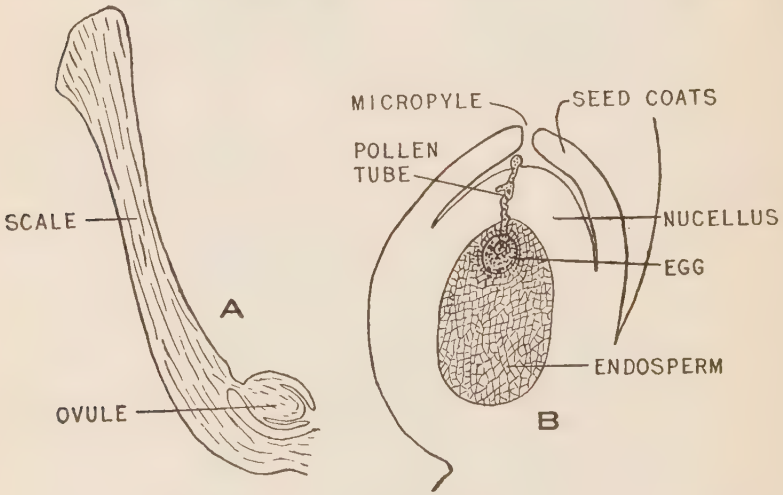

FIG. 287.—The female gametophyte of the pine. *A*, a scale of the carpellate cone at the time of pollination. The ovule contains a megaspore (not shown). *B*, the ovule at the time of fertilization. The endosperm which is shown here represents the prothallus into which food materials now become stored. Note that the cone has reversed its position so that the ovule opening points upward. (*After Atwood.*)

The tip of the tube then breaks and the entire tube contents is emptied into the egg. One of the sperm nuclei fuses with the egg nucleus and fertilizes it forming an oöspore.

Seed Formation and Distribution.—The oöpsore undergoes repeated divisions and forms the *embryo* or young sporophyte plant and a *suspensor* to which it is attached. The embryo is nourished by a portion of the prothallus but the greater part of the prothallus forms the endosperm tissue of the seed surrounding the embryo.

The thin nucellus persists as an endosperm covering. The integument becomes modified to form the hard protective seed coat. A portion of the scale of the cone directly above and adjacent to the ovule forms a membranous wing which separates from the scale as part of the seed.

By this time (about two years after pollination) the scales of the cone, now quite woody, separate, the seeds are shaken out, and many are carried for a considerable distance by winds.

Germination of the Seed.—Under favorable conditions, the seeds absorb water and germinate in the spring following their dispersal.

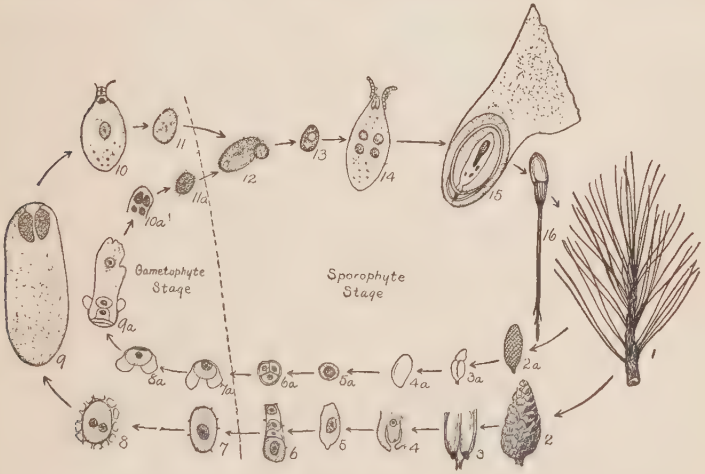

FIG. 288.—Diagram of life-cycle of ā pine. (*From Gager after Schaffner.*)

The hypocotyl of the embryo appears first, arching upward and downward, and, straightening out, draws the green cotyledons with it, which spread out toward the light, while it grows into the soil to form the tap root and in time the remainder of the root system. Thus the seedling sporophyte is formed which in time develops into the mature White Pine tree.

CLASSIFICATION OF CONIFERS

Order Coniferales.—Trees with a single upright stem which develops side branches that spread out horizontally and taper to a

point at the summit, giving the crown of the tree the appearance of a huge cone, rarely shrubs. This order includes two families, the *Pinaceæ* or Pine Family and the *Taxaceæ* or Yew Family.

Pinaceæ (*Coniferæ*) *or Pine Family.*—Trees or shrubs with resinous juice whose wood is characterized by being composed largely of tracheids with bordered pits. Leaves entire, awl- or needle-shaped frequently fascicled, exstipulate, usually evergreen. Flowers, monœcious or rarely dioecious, achlamydeous, in cones. Staminate

FIG. 289.—Inflorescences of the pine. 1, Terminal twig; 2, ovulate cone; 3, staminate cone; 4, two-year-old cone. (*Hamaker.*)

cone of a large number of microsporophylls (stamens) closely packed together and arranged spirally around a central axis, each stamen bearing usually two pollen sacs. Carpellate cone composed of spirally arranged scales, each of which bears a pair of naked ovules (megasori) near the base of its upper face. Fruit a cone with woody or fleshy scales (*Pinus, Thuja, Abies, Picea,* etc.) or a galbulus (*Juniperus*). Seeds albuminous. Embryo with two or more cotyledons.

The following genera of the pine family are of especial pharmaceutic interest:

Genus	Common name
Pinus	Pine
Picea	Spruce
Abies	Fir
Larix	Larch
Tsuga	Hemlock
Thuja	Arbor vitae
Juniperus	Juniper

Official drug	Part used	Botanical origin	Habitat
Terebinthina	Concrete oleoresin	Pinus palustris and other species of Pinus	Southern United States
Resina	Resin	Pinus palustris and other species of Pinu	Southern United States
Oleum Terebinthinæ	Volatile oil	Pinus palustris and other species of Pinus	Southern United States
Pix Pini	Product of destructive distillation	Pinus palustris and other species of Pinus	Southern United States
Oleum Picis Rectificatum	Volatile oil from pine tar		
Pinus Alba	Inner bark	Pinus Strobus	United States and Canada
Oleum Pini Pumilionis	Volatile oil	Pinus montana	Tyrolese Alps
Juniperus	Fruit	Juniperus communis	North America, Europe and Asia
Oleum Juniperi	Volatile oil	Juniperus communis	
Oleum Cadinum	Empyreumatic oil	Juniperus Oxycedrus	So. Europe
Thuja	Leafy young twigs	Thuja occidentalis	United States and Canada
Unofficial drug			
Sabina	Tops	Juniperus Sabina	Europe
Pix Burgundica	Resinous exudate	Picea excelsa	Europe
Terebinthina Canadensis	Liquid oleoresin	Abies balsamea	Northern United States and Canada
Terebinthina Laricis	Oleoresin	Larix europæa	Alps and Carpathians

Unofficial drug	Part used	Botanical origin	Habitat
Sandaraca	Resinous exudate	Callitris quadrivalvis	Africa
Dammar	Resinous exudate	Agathis loranthifolia	E. India
Succinum (Amber)	Fossil resin	Pinites succinifer	Basin of Baltic
Bordeaux Turpentine	Concrete oleoresin	Pinus maritima	France
Pix Canadensis	Oleoresin	Tsuga canadensis	North America
Oregon Balsam	Oleoresin	Pseudotsuga taxifolia	Western United States and British Columbia
Spruce Gum	Gum	Picea canadensis Picea mariana Picea rubra	Canada and New England
Oil of Cedarwood	Oil from wood	Juniperus Virginiana	North America

Taxaceæ or *Yew Family*.—Trees or shrubs with dark green, evergreen, exstipulate, linear leaves without resin ducts and with hard, close-grained wood of a reddish-color. The flowers are usually diœcious; the staminate globular with 4 to 8 stamens each having their anthers under a shield-shaped connective; the pistillate consisting of a single terminal ovule with several bracts at its base. The fruit consists of an erect bony seed situated in a fleshy, reddish-cup-shaped disk.

The leaves, seeds and bark of *Taxus canadensis* (American Yew) and *T. baccata* (European Yew) contain the alkaloid, taxin, which is poisonous to horses, cattle, sheep and pigs. The fleshy disk (aril) surrounding the seed is not poisonous.

THE ANGIOSPERMS

The angiosperms comprise a large assemblage of seed plants which are more highly developed than those of the preceeding group. Like the gymnosperms they possess flowers with sporophylls (stamens and carpels), but the floral axis has been shortened so that the sporphylls and the accessory floral leaves (sepals and petals), when present, are brought closer together on the axis, instead of being separated at strikingly different levels along the axis. The ovules, instead of being borne naked on a scale, are enclosed within the

ovary and the seeds are covered by the ripened wall of the ovary which is called the pericarp or seed vessel.

LIFE HISTORY OF AN ANGIOSPERM (ERYTHRONIUM)

This attractive little plant, commonly called the Dog's Tooth Violet but related to the Lily, is found in the hollows of woods and may be seen in flower during the month of April in the Middle Atlan-

FIG. 290.—Dog's tooth violet (*Erythronium americanum*). Stages of development from the seed. 1–5 show the stage of development in each of five successive years. Full explanation in the text. 6, Bulb showing a surface bud (the sprout has been destroyed. (*Gager after F. H. Blodgett.*)

tic States. It consists of an underground *stem* bearing *scales* (modified leaves) which is termed a *bulb*. From the lower surface of the bulb are given off numerous slender *rootlets* which penetrate the soil and from the upper surface, a pair of oblong, lance-shaped *leaves* of pale green color mottled with purple and white, and later, a *flower stalk* (*scape*), which bears upon its summit a single, yellow, nodding

flower, which is often marked with purple stripes. The flower consists of a *torus* or *receptacle* which will be observed as the upper swollen end of the flower stalk (scape). Inserted upon it, passing from periphery toward the center, will be noted four whorls of floral leaves which, in order, are *calyx*, *corolla*, *andrœcium* and *gynœcium*. The calyx is composed of three lance-shaped and recurved, yellow parts called *sepals;* the corolla of three similarly looking parts called *petals* which alternate in position with the sepals. Both of these whorls are collectively called the *perianth* or floral envelope. The andrœcium or male system of organs is composed of two whorls or circles of structures called *microsporophylls* or *stamens*. There are three *stamens* in each whorl. The outer whorl of stamens will be found opposite the sepals while the inner will be observed opposite the petals. Each stamen (microsporophyll) consists of an awl-shaped stalk or *filament* bearing upon its summit an oblong-linear body called an *anther*. The anther consists of two lobes called *microsori*. Each lobe or microsorus contains two anther sacs or *microsporangia* in which, when mature, are to be found *microspores* or pollen grains. In the center of the flower will be noted the gynœcium or female system of organs. This, upon dissection, will be found to consist of three fused carpellary leaves termed *megasporophylls* (carpels) forming a somewhat flask-shaped structure called a *pistil*. The swollen basal portion of the pistil is called the *ovary;* the stalk which arises from it is called the *style* and the knob-like viscid summit of the style is termed the *stigma*.

Microscopical examination of sections of the ovary will reveal it to be composed of three chambers called *locules*, within each of which are to be noted several inverted *ovules*. Each of these ovules is developed upon a nourishing tissue termed "*placenta*" which connects the ovules to the inner angle of the wall of the locule. The ovule is composed of a central prominent *megasporangium* or *nucellus* which is almost completely invested by two upgrown integuments or coverings. The opening between the tips of the inner integument is called the *micropyle* (little gate). This is the gateway for the entrance of the pollen tube on its way to the nucellus. It is also the exit door for the hypocotyl of the embryo after the fertilized and ripened ovule becomes a seed. Within the nucellus, if the

sections examined have been properly fixed, will be found a *megaspore* or *embryo sac.*

Development of the Female Gametophyte through the Maturation of the Embryo Sac.—In its immature condition the *embryo sac* (*megaspore*) contains a mass of protoplasm surrounding a nucleus. This nucleus undergoes three divisions forming, as a result, eight nuclei which ultimately arrange themselves within the protoplasm of the embryo sac as follows: three of them occupy a position at the apex, the lower nucleus of the group being that of the egg or *ovum,* the other two nuclei being the *synergids* or assisting nuclei; at the opposite end of the sac three nuclei known as *antipodals* take their position; the two remaining nuclei called *polar nuclei* take up a position near the center of the embryo sac. In this condition the contents of the embryo sac constitutes the *female gametophyte.* See Fig. 291 (1–8).

MATURATION OF THE POLLEN GRAIN AND FORMATION OF THE MALE GAMETOPHYTE

The pollen grains (microspores), within the anther sacs, all arise from a number of *tetrads* (groups of four) which are formed by the division and redivision of *pollen mother-cells* preceding them. Each pollen grain, after the tetrads have separated into their components, consists of an outer firm wall or *exosporium,* an inner wall or *endosporium,* within which will be found the region called the *fovilla,* which is nothing other than a mass of protoplasm containing a nucleus. Before the pollen is shed from the anther, its protoplasmic contents undergo a series of changes leading up to the development of the male gametophyte. The nucleus and protopasm enveloping it divides to form two cells, one a generative-cell containing a generative nucleus, the other a tube cell containing a tube nucleus. The generative nucleus then divides to form two sperm nuclei and the partition wall between the two cells disappears. In this condition the protoplasmic contents of the pollen grain constitute the *male gametophyte.* (See Fig. 173.)

POLLINATION AND FERTILIZATION

The mature pollen grains are discharged from the ripened anther through the splitting open of its wall. They are transferred to the

stigma of the pistil of another Erythronium flower through the agency of insects. Here they germinate, each putting forth a tube (pollen tube). The pollen tubes, each carrying within it two sperm nuclei and a tube nucleus embedded in protoplasm, penetrate through the style canal until they reach the micropyles of various ovules. Each enters and passes through a micropyle, then piercing

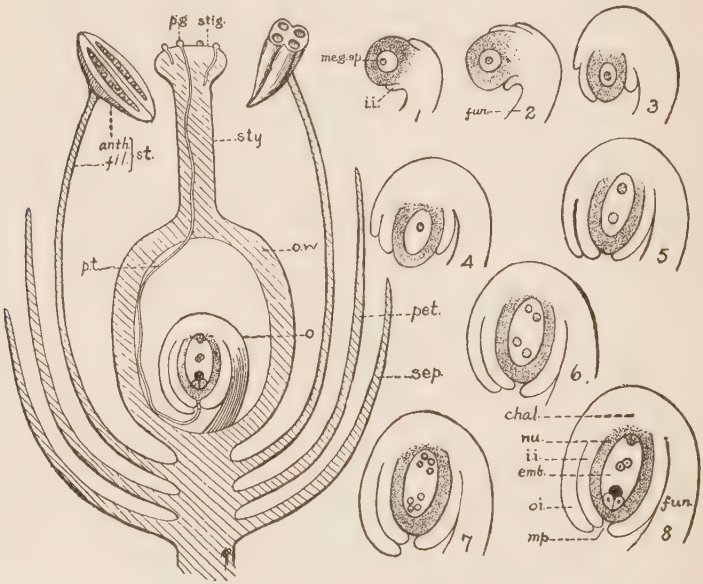

FIG. 291.—At the left, diagram of the anatomy of an angiospermous flower shortly after pollination; *anth.*, anther; *fil.*, filament; *st.*, stamen; *stig.*, stigma; *p.g.*, pollen grains germinating; *sty.*, style; *pt.*, pollen tube; *o.w.*, ovary wall; *o.* ovule, containing embryo-sac; *pet.*, petal; *sep.*, sepal. 1–8, Stages in the development of the female gametophyte (embryo-sac); *meg.sp.*, megaspore-mother-cell; *i.i.*, inner integument; *o.i.*, outer integument; *fun*, funiculus; *chal.*, chalaza; *nu.*, nucellus (megasporangium); *emb.*, embryo-sac. All diagrammatic. (*Gager.*)

the nucellus, grows toward the embryo sac. The tip of the tube fuses with the end of the embryo sac and the two sperm nuclei are discharged into the sac. One of these sperm nuclei passes between the synergids and fuses with the nucleus of the egg to form an *oöspore*. By this time the tube nucleus has disintegrated. The *oöspore* by repeated divisions develops into as many as four *embryos*

or young sporophyte plants. Only one of these, however, persists. The polar nuclei fuse to form the *endosperm nucleus* which soon undergoes rapid division into a large number of nuclei scattered about through the protoplasm of the embryo sac. Later cell walls are laid down and *endosperm* is formed. The endosperm cells soon become filled with abundant starch which is later to be utilized by the embryo during germination.

RIPENING OF THE OVULE TO FORM THE SEED AND OF THE OVARY TO FORM THE FRUIT

When the embryo and endosperm are being formed, the ovule enlarges and its integuments become modified to form a hard, horny, seed coat which encloses the endosperm surrounding the embryo. The ovary, containing the ovules, has by this time ripened to form a three-valved, loculicidal capsule enclosing the seeds.

GERMINATION OF THE SEED AND DEVELOPMENT OF THE MATURE SPOROPHYTE

The seeds are fully developed by June or July when the capsule or fruit splits open to discharge them. They fall to the ground and lie dormant until the following spring when they germinate or commence to grow. Each seed absorbs water from the ground which stimulates the ferment amylase, contained in the endosperm cells, to break up the insoluble starch into soluble sugar which passes into solution and diffuses into the cells of the embryo, where the protoplasm changes it into additional protoplasm and so the embryo increases in size, therefore, *grows*. The pressure of the swollen endosperm and growing embryo becomes so great that the seed coat bursts; the hypocotyl emerges first, dragging the cylindrical cotyledon out of the seed coat and epicotyl with it. The hypocotyl elongates and extends itself into the soil where it develops a root near its tip. The tip enlarges through the storage of starch, manufactured by the green cotyledon and becomes a bulb. The bulb soon develops within it a plumule, the cotyledon withers, and the young plant (seedling) passes the following winter in this condition.

During the next spring the plumule develops into a foliage leaf and the bulb gives rise from its base to several slender elongated *runners*,

which, at their tips, develop *runner bulbs*. These runner bulbs, the third year, give origin to another set of runners similar to those formed during the second year which also develop runner bulbs at their tips. A foliage leaf is also formed by each. The following spring (spring of fifth year after formation and shedding of seed) one of these bulbs develops into a mature sporophyte plant, bearing a single flower at the summit of its elongated scape. See Fig. 290.

RESEMBLANCES BETWEEN GYMNOSPERMS AND ANGIOSPERMS

1. In both are developed flowers.

2. In both the flowers develop at least two sets of leaves (either on one or two plants of the same species) called sporophyll leaves, the stamens and carpels. The stamens or staminal leaves are also termed microsporophylls. The carpels or carpellate leaves are also known as megasporophylls.

3. Both groups produce microspores or pollen grains and megaspores or embryo sacs.

4. In both are developed on the evident generation, the plant or sporophyte and the gametophyte, the latter concealed within the megaspore of the sporophyte.

5. Both develop seeds with one or two seed coats.

6. In both groups there is developed from the fertilized egg an embryo which lies within the cavity of the megaspore.

7. In both there exists a root and a stem pericambium.

8. Both produce collateral vascular bundles. Very rarely do we meet with concentric bundles in the stem or leaf of Angiosperms.

FUNDAMENTAL DIFFERENCES BETWEEN GYMNOSPERMS AND ANGIOSPERMS

1. The flowers of Gymnosperms are often monœcious or diœcious but very rarely hermaphrodite (as in *Welwitchia*), whereas those of Angiosperms are usually hermaphrodite, rather rarely monœcious, still more rarely diœcious.

2. In the Gymnosperms the sporophylls are usually inserted either spirally or in whorls around a distinctly elongated axis, whereas in Angiosperms the sporophylls are condensed to short whorls or spirals set around a shortened axis, the floral axis or recep-

tacle, torus or thalamus, or, as in the more modified Angiosperms, the floral axis may even become hollow.

3. In Gymnosperms the microsporophylls or stamens are usually sessile, whereas in Angiosperms the microsporophylls are nearly always stalked. Rarely do we find sessile anthers among Angiosperms, an instance of this being seen in Mistletoe (*Viscum*) where the anthers are set on the staminal leaf.

4. In Gymnosperms there is a traceable prothallus or gametophyte plant that later becomes the so-called "endosperm" of the gymnosperm, whereas in Angiosperms no recognizable prothallus has been proven to exist.

5. The stored food tissue in Gymnosperm seeds is prothallial tissue loaded with starch, etc., whereas in Angiosperm seeds the stored food tissue (endosperm) is a special formation after fertilization.

6. Gymnosperms bear naked ovules and seeds while Angiosperms bear covered ones.

7. In Gymnosperms there are distinct recognizable archegonia formed on or imbedded in the prothallus, whereas in Angiosperms there are no distinct archegonia, only an isolated egg or eggs.

8. In Gymnosperms there are not infrequently found several embryos from one fertilized egg. This condition is called *polyembryony*. Polyembryony is unknown in Angiosperms, only a *false polyembryony* being noticed.

9. In Gymnosperms the secondary xylem (wood) tissue of roots, stems and leaves consists either of punctated or scalariform cells, whereas in Angiosperms the secondary wood tissue may be varied in structural aspect.

CLASSES OF ANGIOSPERMS

The Angiosperms are subdivided into two classes, the Monocotyledoneæ or Monocotyledons, and the Dicotyledoneæ or Dicotyledons.

The Monocotyledons include such plants as the cat-tails, grasses, sedges, palms, lilies, daffodils, irises, bananas, gingers and orchids. The Dicotyledons are represented by a vast array of plants which include nearly all the familiar trees and shrubs except the conifers

and the majority of weeds, garden plants, and ornamental herbs which have netted veined leaves.

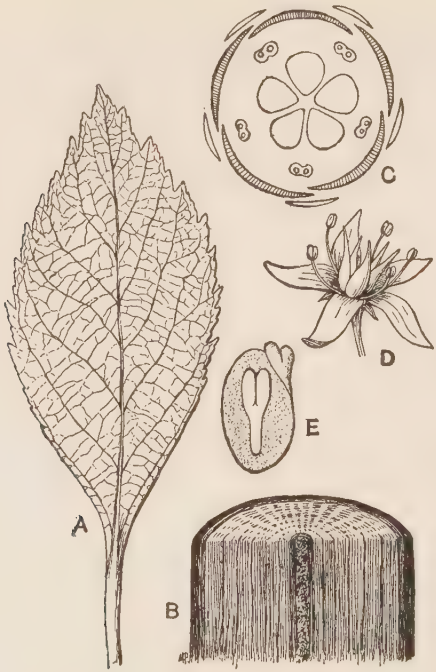

FIG. 292.—Morphology of a typical dicotyledonous plant. *A*, leaf, pinnately-netted veined; *B*, portion of stem, showing concentric layers of wood; *C*, ground-plan of flower (the parts in 5's); *D*, perspective of flower; *E*, longitudinal section of seed, showing dicotyledonous embryo. (*Gager.*)

The Dicotyledons are undoubtedly more primitive plants than the Monocotyledons, the latter having been derived from a dicotyledon ancestry.

CHAPTER XXIII

THE DICOTYLEDONS

The Dicotyledons are a class of angiosperms having the following characteristics:

Two-seed leaves (cotyledons) in embryo, these being lateral on the embryonic axis.

Foliage leaves with pinnate-reticulate or palmate-reticulate veins.

Stems, leaves, and roots of secondary growth with open collateral or bi-collateral fibro-vascular bundles; in stems radially arranged about pith.

Exogenous stems.

Medullary-rays present.

Cambium present in the plant axis.

Roots developing secondary structure.

Flowers tetramerous or pentamerous (parts of each whorl, four or five or multiple thereof).

This is the largest class of angiosperms containing more than 100,000 species of described plants which have been grouped into 240 families. We shall consider in this chapter only those groups of dicotyledons which yield drugs.

DRUG YIELDING DICOTYLEDONS

Sub-Class Archichlamydeæ

Those dicotyledonous plants in which the petals are distinct and separate from one another or are entirely wanting. That group of the Archichlamydeæ whose flowers show the absence of petals and frequently of sepals is called the *Apetalæ*. The group whose plants have flowers showing the parts of their corolla (petals) separate and distinct is called the *Choripetalæ* or *Polypetalæ*.

ORDER PIPERALES

Piperaceæ or Pepper Family.—A family of apetalous aromatic herbs and shrubs with jointed stems, opposite, verticillate, or sometimes alternate leaves without stipules, and spiked, inconspicuous, wind-pollinated flowers. The characteristic fruit is a drupe enclosing a single upright seed with abundant perisperm (from megasporangial tissue) and reduced endosperm (from matured embryo sac).

FIG. 293.—At left, fruiting branch of Black Pepper (*Piper nigrum*). Portion of shoot with inflorescences. Terminal portion of an inflorescence (enlarged). (*After Wossildo.*)

At right, the Cubeb (*Piper Cubeba*). *a*, cluster of fruit; *b*, staminate flower; *c*, pistillate flower in longitudinal section; *d*, fruit in longitudinal section. (*After Berg and Schmidt.*) *Both from Gager after Strasburger, Noll, Schenck and Schimper.*

Official drug	Part used	Botanical name	Habitat
Cubeba	Unripe fruit	Piper Cubeba	Borneo, Java Sumatra
Piper	Unripe fruit	Piper nigrum	Cochin-China, India
Kava	Rhizome and roots	Piper methysticum	Sandwich Islands
Matico	Leaves	Piper angustifolium	Peru, Bolivia
Unofficial drug			
Piper Longum	Spike of immature fruit	Piper longum Piper officinarum	Asia

ORDER SALICALES

Salicaceæ or Willow Family.—Shrubs or trees of temperate or cold regions, with upright woody stems, rarely herbs (*Salix retusa*). Bark often containing bitter principles (Salicin, etc.).

Leaves alternate, simple, entire, stipulate; stipules rarely green, persistent, usually functioning as winter bud-scales and falling in spring.

FIG. 294.—Willow (*Salix*). Leafy branch, bearing two pistillate catkins, Staminate flower above, at the left; pistillate flower below, at the right. (*Gager after Britton and Brown.*)

Inflorescences diœcious spikes, so on separate plants. Staminate spikes forming deciduous catkins of yellowish flowers, pistillate as persistent spikes of green flowers, at length maturing fruit.

Flowers of catkins numerous, each of two to five (Willow) or six to fifteen (Poplar); stamens in axil of a small bract leaf, sometimes with small nectar knob or girdle at base; pollen abundant, hence plants anemophilous, rarely entomophilous. Pistillate flowers

green, each of a bicarpellate pistil in axil of bract, ovary one-celled with parietal placentation, style simple, stigma bilobed.

Fruit a capsule dehiscing longitudinally. Seeds small, exalbuminous, surrounded by a tuft of hairs for dissemination.

FIG. 295.—Two *Myrica cerifera* trees growing in a field near a brackish swamp at Rio Grande, N. J. Photographed by author, July 26, 1914.

Official drug	Part used	Botanical name	Habitat
Salicinum	Glucoside	Several species of Salix and Populus	Europe, North America
Populi Gemmæ	Closed leaf buds	Populus nigra	Europe
		Populus balsamifera	North America
		Populus candicans	
Unofficial drug			
Salix	Bark	Salix alba	Europe

ORDER MYRICALES

Myricaceæ or Bayberry Family.—Dicœcious or sometimes monœcious, aromatic shrubs or trees with watery juice and possessing underground branches which arch downward then upward producing

FIG. 296.—Fructiferous branches of *Myrica Caroliniensis* (to left) and *Myrica cerifera* (to right) as they appear in early winter. The former species is deciduous while the latter is evergreen. Collected by author at Wildwood, N. J., Dec. 16, 1914.

many suckers. Roots fibrous and bearing many short rootlets upon which are frequently found coralloid clusters of tubercles containing the *Actinomyces Myricarum* Youngken. Leaves alternate, revolute

in vernation, serrate, irregularly dentate, lobed or entire, rarely pinnatifid, pinnately and reticulately veined, pellucid-punctate, evergreen or deciduous, generally exstipulate, rarely stipulate.

FIG. 297.—Fructiferous branch of *Myrica Gale*, showing mature pistillate catkins and nature of leaves. Collected at the south end of Peak's Island in Casco Bay, Maine, September, 1913.

Flowers naked, unisexual, monœcious or diœcious, in the axils of unisexual or androgynous aments from scaly buds formed in the summer in the axils of the leaves of the year, remaining covered

during the winter and opening in March or April before or with the unfolding of the leaves of the year.

Staminate flowers in elongated catkins, each consisting of two to eight stamens inserted on the torus-like base of the oval or oval-lanceolate bracts of the catkin, usually subtended by two or four or rarely by numerous bracteoles; filaments short or elongated, filiform, free or connate at the base into a short stipe; anthers ovoid, erect, two-celled, extrorse, showing longitudinal dehiscence. Pistillate flowers in ovoid or ovoid-globular catkins. Gynœcium of two united carpels on a bract. Ovary sessile, unicellular, subtended by two lateral bracteoles which persist under the fruit, or by eight linear-subulate bracteoles, accrescent, and forming a laciniate involucre inclosing the fruit; styles short and dividing into two elongated style arms which bear stigmatic surfaces on their inner face; ovule orthotropous, solitary, with a basilar placenta and superior micropyle. Fruit an akene or ceriferous nut. Pericarp covered with glandular emergences which secrete wax or fleshy emergences, smooth and lustrous or smooth, glandular. Seed erect, exalbuminous, covered with a thin testa. Embryo straight, cotyledons thick, plano-convex; radicle short, superior.

There are two distinct genera of this family, *e.g.*, *Myrica* and *Comptonia*.

Official drug	Part used	Botanical name	Habitat
Myrica	Bark of root	Myrica cerifera Myrica carolinensis	Eastern North America

ORDER JUGLANDALES

Juglandaceæ or Walnut Family.—Tall, branching, monœcious trees or shrubs with branches and leaf-stalks usually beset with glandular-resinous hairs. Leaves alternate, exstipulate and odd-pinnate which, upon falling, leave usually horse-shoe shaped scars on branches, and in whose axils develop frequently one axillary bud and several ascending accessory buds. Inflorescence of staminate catkins and pistillate spikes. The staminate catkins occur on the old wood of the previous year. The pistillate spikes are borne at the extremity or on sides of the new wood. The staminate

flower is composed of an elongated floral disk bearing a terminal bract, perianth of 6 to rarely 4 parts and 40 to 4 stamens. The pistillate flower is composed of an upgrown, hollowed-out receptacle bearing on its margin or extremity 5 to 4 perianth segments and containing a pistil consisting of an inferior ovary with a single ovule and 2 styles having radiating penicillate stigmas. Fruit a drupe composed of fused receptacular tube and ovarian wall and exhibiting a leathery to rarely membranous epicarp, more or less succulent mesocarp, and stony endocarp enclosing a seed with a double layered seed coat surrounding an enlarged embryo with irregular, semi-ruminate cotyledons, into and between which the fruit and seed layers grow.

The family embraces six genera, of which *Carya* (Hickories) and *Juglans* (Walnuts) are represented in the United States.

Official drug	Part used	Botanical name	Habitat
Juglans	Inner root bark	Juglans cinerea	United States

ORDER FAGALES

Betulaceæ or Birch Family.—A family of aromatic trees or shrubs distinguished by monœcious flowers with scaly bracts and astringent resinous bark. Differs from *Fagaceæ* by superior ovary and absence of cupule. To this family belong the hazelnuts, birches, alders, the ironwood, and the hornbeams.

Official drug	Part used	Botanical name	Habitat
(Oleum Betulæ) Methylis salicylas	Volatile oil	Betula lenta	North America
Oleum Betulæ Empyreumaticum Rectificatum	Pyroligneous oil	Betula alba	Eurasia

Fagaceæ or Beech Family (*Cupuliferæ*).—*Beeches, Chestnuts, Oaks,* the trees of this family, are found in the temperate forests of the eastern and western hemispheres and comprise about 368 species. North America has over 50 species of oaks; 2 species of Chestnuts; 1 species of beech and 1 species of golden-leaved chestnut. The most important American oaks used for building, for furniture, for cooperage, for wagons, for tanning leather etc. are white oak, *Quercus alba;* chestnut oak, *Q. prinus;* black oak, *Q. velutina;* live oak, *Q. virgini-*

ana; swamp white oak, *Q. platanoides;* cow oak, *Q. Michauxii,* and the two Pacific coast oaks, *Q. chrysolepis* and post oak, *Q. garryana.*

FIG. 298.—*Quercus infectoria*—Branch and nutgall. (*Sayre.*)

The uses of the fast disappearing Chestnut, *Castanea dentata,* are well known. The wood of the beech, *Fagus grandifolia,* is used for chairs, tool handles, plane stocks, shoe lasts and for fuel. The

nuts (mast) fatten hogs and feed wild animals and birds. The cork of commerce is obtained from the bark of *Quercus Suber* and *Quercus occidentalis*, plants indigenous to Spain and France.

FIG. 299.—Hop (*Humulus lupulus*), a member of the *Moraceæ*. *A*, portion of plant showing pistillate inflorescences; *B*, staminate inflorescence; *C*, rachis of pistillate inflorescence ("hop"). (*Robbins.*)

The above trees are all monœcious, that is the staminate (male) and pistillate (female) flowers are distinct from each other, but borne on the same tree. Most of the species are trees, a few oaks are shrubs. The leaves are simple, netted-veined and alternate. A pair of deciduous stipules are found at the base of the leaf-stalk (petiole). The margins of the chestnut and beech leaves are sharply cut with large teeth. The leaves of the oaks divide the genus into two groups, viz.—the white oaks with rounded lobed leaves and annual acorn production, and the black oaks with sharp bristle-tipped lobes and biennial acorn production. The male flowers are in dangling heads (beech), or in catkins (chestnut and oaks). The male flowers have a united perianth, which is 4-6 parted and encloses an indefinite number of undivided stamens. The female flowers have a superior 6-parted perianth; the pistil consisting of 3 carpels with a corresponding number of stigmas. The ovary is 3-6 celled and each cell has 2 pendulous ovules. The fruit is a one-seeded nut. The cup, or cupule, in the beech is 4 sided and covered externally with weak spines and encloses two 3 sided seeds. The cupule in the chestnut forms the spiny bur, which splits into 4 valves at maturity, enclosing 3 nuts. The cupule in the oak is saucer-, or cup-shaped, and encloses a single rounded nut, or acorn. The seeds are exalbuminous and the cotyledons are thick and fleshy, edible in the beech, chestnut and a few of the oaks.

Official drug	Part used	Botanical name	Habitat
Galla	Excrescence	Quercus infectoria	Europe and W. Asia
Castanea	Leaves	Castanea dentata	North America
Quercus	Inner bark	Quercus alba	North America
Acidum Tannicum	Tannin from gall	Quercus infectoria	Europe

ORDER URTICALES

Ulmaceæ or *Elm Family.*—Forest trees indigenous to the temperate and tropical zones, characterized by being woody plants, with simple, often inequilateral, pinnately-veined leaves having caducous stipules and without milky juice. Their flowers are unisexual or hermaphroditic with six or four parts to the calyx. Fruit a single winged samara (Elms) or a drupe (Hackberry).

Official drug	Part used	Botanical name	Habitat
Ulmus	Inner bark	Ulmus fulva	United States and Canada

FIG. 300.—*Cannabis sativa* or Indian Hemp (Fam. *Moraceæ*). At left, staminate plant, bearing axillary panicles of staminate flowers. At right, young pistillate plant whose panicles constitute the drug Cannabis. Note the palmately compound leaves, the leaflets of which are lanceolate with serrate margins.

Moraceæ or Mulberry Family.—Mostly apetalous shrubs or trees, rarely perennial herbs, many of them containing a milky juice, with small, axillary, clustered or solitary, unisexual flowers, variously colored; leaves ovate with serrate margin and having caducous stipules; fruit an akene enclosed by the persistent perianth.

Official drug	Part used	Botanical name	Habitat
Cannabis	Flowering tops of pistillate plant	Cannabis sativa	Asia
Ficus	Fruit	Ficus Carica	Persia
Humulus	Strobile	Humulus lupulus	Europe, Asia
Lupulinum	Glandular trichome	Humulus lupulus	North America

ORDER SANTALALES

Santalaceæ or Sandalwood Family.—Herbs, shrubs or trees having entire exstipulate leaves, greenish flowers, nut-like or drupaceous fruits and oily seeds. Many are parasitic on the roots of other plants or on trees.

Official drug	Part used	Botanical name	Habitat
Oleum Santali	Volatile oil	Santalum album	India and Malaya
Santalum Album	Heartwood		

ORDER ARISTOLOCHIALES

Aristolochiaceæ or Birthwort Family. Herbs or twining semi-woody or woody plants, having more or less swollen nodes from which spring alternate cordate or reniform or ovate leaves. Flowers regular (*Asarum*, etc.) or irregular (*Aristolochia*), often offensively smelling. Sepals varying from 6 to rarely 5 to more commonly 4 or 3; in *Asarum*, etc. forming a regular symmetrical cup with 3 teeth or lobes, in *Aristolochia* divisible into a bowl, a tube and a limb. Stamens from 24 to 3, the filaments distinct or slightly fused with styles, in *Asarum*, or completely fused, in *Aristolochia*, to form a gynostemium, the anthers separate. Pistil of as many carpels as stamens, the stylar portions more or less distinct from stamens in *Asarum*, fused in *Aristolochia*, the ovary semi-inferior to inferior in *Asarum*, completely inferior in *Aristolochia* and as many celled as there are *carpels*. Fruit a capsule. Seeds with copious albumen and minute embryo.

FIG. 301.—*Aristolochia Serpentaria.* (*Sayre.*)

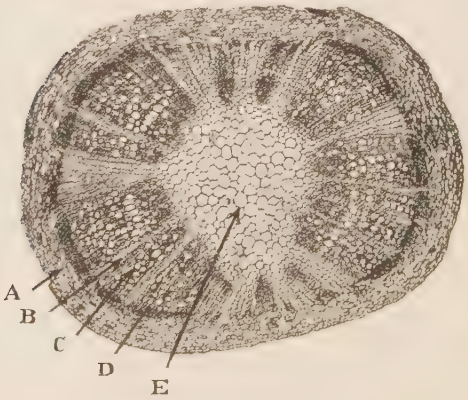

FIG. 302.—Serpentaria—Cross-section of rhizome. (25 diam.) *A*, parenchyma of cortex; *B*, medullary ray; *C*, xylem; *D*, phloem; *E*, medulla. (*Sayre.*)

Official drug	Part used	Botanical name	Habitat
Serpentaria	Rhizome and roots	Aristolochia Serpentaria Aristolochia reticulata	United States
Asarum	Rhizome and roots	Asarum canadensis	United States

ORDER POLYGONALES

Polygonaceæ Family.—Usually herbs [Knot-grasses (*Polygonum*), rhubarb (*Rheum*), docks (*Rumex*), buckwheat (*Fagopyrum*), etc.] rarely trees (*Coccoloba uvifera* or Sea-Grape) or shrubs (*Muehlenbeckia* or Ribbon Bush) having strong vertical tap roots and spreading secondary roots more or less provided with tannin compounds. Stems elongate, green, to woody, rarely flattened, leathery, phylloidal (*Muehlenbeckia platyclada*), still more rarely tendriliform (*Antigonon leptopus* or Mountain Rose of Tropical America). Leaves alternate, rarely opposite or whorled (*Eriogonum*), entire,

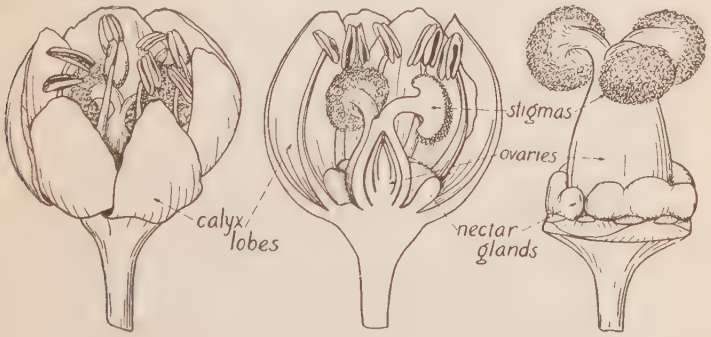

Fig. 303.—Rhubarb (Rheum) flower, external view, median lengthwise section, and with perianth and stamens removed. (*Robbins, after Luerssen.*)

rarely lobed (*Rheum palmatum, Rumex acetosella*), petiolate, rarely sessile, and stipulate. Stipules fused and forming a greenish membranous upgrowth (*ocrea*) which sheaths the stem. Inflorescence racemose with many dense scorpioid or helicoid cymes, which in some forms condense into single flowers. Flowers regular, pentamerous, with simplex calyx, becoming trimerous with two whorls of three sepals each. Stamens varying from fifteen or twelve to

nine or six, more rarely to five, four, three to one (*Kœnigia*), hypogynous, more rarely by enlargement of receptacle and slight fusion of sepals, perigynous. Pistil tri- to bi-carpellate, often three- to two-sided, ovary one-celled with one ovule. Styles three, rarely two, radiating penicillate in wind-pollinated inconspicuous flowers, becoming condensed knob-like in conspicuous insect-pollinated flowers. Fruit a triangular or biconvex akene often crowned by persistent styles and surrounded by persistent closely applied sepals. Seeds solitary, albuminous, with straight embryo, or in *Rumex*, curved embryo.

Official drug	Part used	Botanical origin	Habitat
Rheum	Rhizome and roots deprived of periderm	Rheum officinale Rheum palmatum and other species of Rheum grown in China and Thibet	China and Thibet
Rumex	Root	Rumex crispus Rumex obtusifolius	Europe
Unofficial			
Bistorta	Rhizome	Polygonum Bistorta	Europe and Asia

ORDER CHENOPODIALES OR CENTROSPERMÆ

This order contains seven families, all of which have seeds with a curved or coiled embryo. These families are the Goosefoot Family (*Chenopodiaceæ*), the Pokeweed Family (*Phytolaccaceæ*); The Amaranth Family (*Amaranthaceæ*) which includes the ornamental Cock's Comb; the Four-o'clock Family (*Nyctaginaceæ*) to which belong the Marvel of Peru or Four-o'clock and the beautiful Bougainvilleas; The *Aizoaceæ* containing the Carpet Weed (*Mollugo verticillata*) and the Sea Purslane (*Sesuvium maritimum*), etc.; The Portulaca Family (*Portulacaceæ*) which is represented by the Spring Beauty (*Claytonia virginica*) and the Purslane (*Portulaca*); The Pink Family (*Caryophyllaceæ*) which includes the Carnations, Bouncing Bet, etc.

Chenopodiaceæ or *Goosefoot Family.*—Usually herbaceous halophytes or shore growers, growing also in any alkaline soil, more rarely shrubs (*Atriplex*) or low trees (*Haloxylon*).

Among them are several garden vegetables (*Spinach, Beets, Mangels*) and a number of weeds. Leaves alternate to opposite

FIG. 304.—*Phytolacca americana* (in foreground), growing in damp woodland.

sometimes reduced to teeth, entire or lobed. Inflorescence spikes or short racemes of condensed cymes. Flowers regular, usually small and greenish. They are either perfect (*Beta*), monœcious (*Chenopodium*), dioecious (*Atriplex* sp.), or polygamous (*Kochia* or

Summer Cypress). Fruit a utricle. Seed albuminous. Embryo curved, enclosing central albumen.

Official drug	Part used	Botanical name	Habitat
Oleum Chenopodii	Volatile oil	Chenopodium anthelminticum	United States
Sucrosum	Refined sugar	Beta vulgaris	Europe
Unofficial			
Chenopodium	Fruit	Chenopodium anthelminticum	United States

Phytolaccaceæ or Poke Family.—A family of apetalous trees, shrubs, or woody herbs—the pokeweed family—with alternate entire leaves, and flowers resembling those of the goosefoot family (*Chenopodiaceæ*), but differing in having the several-celled ovary composed of carpels united in a ring, and forming a berry in fruit. It embraces 21 genera, and 55 species, mostly tropical and sub-tropical.

Official drug	Part used	Botanical name	Habitat
Phytolacca	Root	Phytolacca americana	North America

ORDER RANALES

This order includes the following families: *Nymphaeaceæ* or Water Lily Family, *Magnoliaceæ* or Magnolia Family, *Ranunculaceæ* or Crowfoot Family, *Berberidaceæ* or Barberry Family, *Menispermaceæ* or Moonseed Family, *Anonaceæ* or Custard Apple Family, *Myristicaceæ* or Nutmeg Family, *Monomiaceæ* or Boldo Family, and *Lauraceæ* or Laurel Family.

Magnoliaceæ or Magnolia Family.—Trees and shrubs having alternate leaves with large deciduous stipules that enclose the young buds and single large flowers with several series of sepals and petals which are often colored alike. Sepals and petals deciduous. Carpels and stamens numerous and free. Bark aromatic and bitter. Fruit a collection of follicles dehiscing dorsally. Seeds large, albuminous and oily.

To this family belong the stately Tulip Poplar, prized for its wood and beautiful flowers and the showy Magnolias of our gardens.

Official drug	Part used	Botanical name	Habitat
Oleum Anisi	Volatile oil	Illicium verum	South China
Unofficial			
Winter's Bark	Bark	Drimys Winteri	South America

FIG. 305.—*Hydrastis canadensis* (Fam. *Ranunculaceæ*) × ½. At left, the apocarpous aggregate fruit. (*After Strasburger, Noll, Schenck and Schimper.*)

Ranunculaceæ or *Buttercup Family.*—Herbs, rarely shrubs (*Clematis*) with acrid, poisonous, watery juices and with alternate, rarely

opposite, simple, rarely compound, exstipulate leaves. Flowers pentamerous, regular to irregular, incomplete to complete, aposepalous and apopetalous. Sepals five—rarely more or less—green to petaloid, regular, passing to irregular (Larkspur, Monkshood). Petals none or five, regular to rarely irregular, often nectariferous and with nectariferous petals often variously transformed. Sta-

FIG. 306.—Above ground portion of *Aconitum Napellus* (Monkshood) showing palmately-divided leaves and hooded flowers.

mens indefinite, hypogynous. Pistil of many to few apocarpous carpels, each carpel with one to several ovules. Fruit a collection of achenes (*Ranunculus*, *Anemonella*), or a collection of follicles (Columbine, Larkspur, Peony, Aconite) or rarely a berry as in Baneberry (*Actæa*). Seeds albuminous with large oil-containing endosperm and small embryo.

FIG. 307.—*Cimicifuga racemosa*—Plant and rhizome. Note the pinnately decompound leaf and the wand-like racemes which bear white flowers. (*Sayre.*)

Official drug	Parts used	Botanical name	Habitat
Hydrastis	Rhizome and roots	Hydrastis canadensis	Eastern United States and Canada
Aconitum	Tuberous root	Aconitum Napellus	Europe, Asia
Cimicifuga	Rhizome and root	Cimicifuga racemosa	E. North America
Pulsatilla	Entire herb	Pulsatilla vulgaris	Europe and Asia
		Pulsatilla pratensis	
		Pulsatilla patens	W. North America
Coptis	Entire herb	Coptis trifolia	United States and Canada
Adonis	Overground portion	Adonis vernalis	Europe and Asia
Delphinium	Seed	Delphinium Ajacis	Europe
Unofficial			
Aconiti Folia	Leaves and flower tops	Aconitum Napellus	Europe and Asia
Helleborus	Rhizome and roots	Helleborus niger	Alps
Staphisagria	Seed	Delphinium Staphisagria	South Europe, Asia Minor

Berberidaceæ or Barberry Family.—Herbs and woody plants with watery juices and alternate or radical, simple or pinnately-compound, mostly exstipulate leaves often bearing spines or barbs, which give them a barbed appearance. Rhizomes and roots often of yellow color internally, due to berberine content. Flowers either in racemes of cymes, cymes, racemes or solitary. Sepals and petals usually in 2 series of 3 each, similar, hypogynous; stamens 9 to 4, hypogynous; pistil single. Fruit a berry or capsule. Seeds exalbuminous with a straight large embryo in axis of albumen.

Official drug	Parts used	Botanical name	Habitat
Berberis	Rhizome and roots	Berberis species of the Sect. Mahonia	Western North America
Podophyllum	Rhizome and roots	Podophyllum peltatum	Eastern North America
Caulophyllum	Rhizome and roots	Caulophyllum thalictroides	Eastern North America

Menispermaceæ, or Moonseed Family.—Choripetalous, woody, climbing, mostly tropical plants with alternate, exstipulate, simple often peltate leaves. Flowers green to white. Fruit a one-seeded succulent drupe. Seeds albuminous. They usually contain tonic, narcotic or poisonous bitter principles.

Official drug	Parts used	Botanical name	Habitat
Calumba	Root	Jateorhiza palmata	East Africa
Pareira	Root	Chondodendron tomentosum	Peru and Brazil
Cocculus	Fruit	Anamirta cocculus	Asia
Unofficial			
Menispermum	Rhizome and roots	Menispermum canadense	United States and Canada

FIG. 308.—*Podophyllum peltatum.* Entire plant, above ground portion, and fruit. Note the flowering stems bearing in each instance two one-sided leaves and a nodding flower from the forks. This plant also sends up from its rhizome flowerless stems each of which terminates in a 7–9 lobed peltate leaf.

Myristicaceæ or Nutmeg Family.—An order of apetalous trees comprising the genus *Myristica*, of about 80 species.

Myristica.—A large tropical genus of fragrant, apetalous trees—the nutmegs—coextensive with the nutmeg family, having alternate,

FIG. 309.—*Jateorhiza palmata*—Portion of vine. Note tendril for winding about a support as this plant climbs. (*Sayre.*)

entire, often pellucid punctate leaves, small diœcious, regular flowers, and a succulent, two-valved, one-celled fruit with a solitary seed containing ruminate albumen and covered by a fleshy arillus.

M. fragrans, a handsome tree, 20 to 30 feet high, indigenous to the Indian archipelago but now cultivated extensively in the West Indies, supplies the nutmegs and mace of commerce.

Official drug	Part used	Botanical name	Habitat
Myristica	Kernel of seed	Myristica fragrans	Molucca Islands
Oleum Myristicæ	Volatile oil	Myristica fragrans	
Unofficial drug			
Macis	Arillode	Myristica fragrans	

FIG. 310.—*Myristica fragrans*—Branch and fruit. (*Sayre.*)

Monomiaceæ or Boldo Family.—Tropical trees and shrubs with opposite or rarely alternate, entire or serrate, pellucid-punctate leaves devoid of stipules.

Flowers hermaphrodite or unisexual in cymes or racemes; calyx of many to 4 lobes or teeth in 2 or more series, stamens numerous to few, hypogynous, carpels several to one, each with a single ovule. Fruit a drupe (*Boldu*), nut or achene. Seeds with membranous testa and fleshy endosperm.

Official drug	Part used	Botanical name	Habitat
Boldus	Leaf	Boldu Boldus	Chile

FIG. 311.—*Cinnamomum zeylanicum*—Branch. (*Sayre.*)

Lauraceæ or Spicebush Family.—Shrubs or trees of sub-tropical or tropical, rarely of temperate regions. Bark, wood and leaves rich

in spicy, aromatic, hydrocarbon oils. Leaves alternate, simple, entire, often leathery and shining and exstipulate. Inflorescenes usually cymose clusters. Flowers small, green, yellow or rarely whitish, hermaphrodite or more or less dicœcious; regular calyx alone present as a floral whorl, of three to six small sepals. Stamens four to twelve in several rows of three to four each; anthers continuous with the filaments, each anther opening by recurved valves, the valves opening from the base upward. Pistil monocarpellary, ovary superior, one-celled with solitary pendulous ovule, style simple with usually rounded stigma. Fruit a succulent berry (Spicebush and "Bacca laurea") or a succulent drupe (Sassafras). Seeds usually richly albuminous.

Official drug	Part used	Botanical name	Habitat
Camphora	Ketone	Cinnamomum Camphora	Eastern Asia
Sassafras	Bark of root	Sassafras variifolium	North America
Oleum Sassafras	Volatile oil from root	Sassafras variifolium	North America
Sassafras Medulla	Pith	Sassafras variifolium	North America
Cinnamomum	Bark	Cinnamomum Loureirii	Cochin China
Oleum Cinnamomi	Volatile oil	Cinnamomum Cassia	China
Unofficial			
Cinnamomum Zeylanicum	Bark	Cinnamomum Zeylanicum	Ceylon
Coto	Bark	Nectandra Coto	Bolivia
Laurus	Leaves	Laurus nobilis	Europe North America
Fagot cassia	Bark	Cinnamomum Burmanii	Asia
Clove Bark	Bark	Dicypellium caryophyllatum	Brazil
Cassia Buds	Immature fruit	Cinnamomum Loureirii	Cochin China
Cassia Bark	Bark	Cinnamomum Cassia	China

ORDER RHŒADALES (PAPAVERALES)

Papaveraceæ or Poppy Family.—Herbs or low shrubs. Root only, in some cases root and stem, and in still others the entire plant, traversed by anastomosing latex tubes that contain a milky juice varying from white (*Papaver*) or pale-yellow as in Celandine (*Cheli-*

FIG. 312.—*Papaver Somniferum*—Flowering branch and fruit. (*Sayre.*)

donium) to red (*Bloodroot*). Latex tubes wholly confined to cortex or phloem but occasionally sending branches into the medullary rays, rarely into the pith of the plant. Leaves alternate, varying from simple (*Platystemon*) to pinnatifid, pinnatipartite or even

pinnately-compound. Inflorescence varying from a loose raceme or panicle of cymes to a raceme of cymes or condensing until, as in *Papaver*, only one large terminal flower is left. Flowers regular tetramerous or dimerous. Sepals typically two, more rarely three. Petals typically four, more rarely six. Stamens indefinite, in most forms hypogynous, except in California Poppy (*Eschscholtzia*) where hypogyny is modified into perigyny. Pistil of sixteen to four, rarely two carpels generally fused together. Placenta parietal. Ovules numerous, anatropous. Fruit a capsule except in *Platystemon* which has follicles. Seeds richly albuminous.

Official drug	Part used	Botanical name	Habitat
Opium	Air-dried milky exudate	Papaver somniferum and its *var.* album	Eastern Mediterranean countries
Sanguinaria	Rhizome and roots	Sanguinaria canadensis	United States and Canada
Unofficial			
Chelidonium	Entire flowering plant	Chelidonium majus	United States and Canada
Maw seed	Seeds	Papaver somniferum	Eastern Mediterranean countries
Papaveris Fructus	Unripe capsules	Papaver somniferum	Eastern Mediterranean countries

Fumariaceæ or Fumitory Family.—Delicate herbs, rarely shrubs containing milky-watery to watery latex. Leaves radical, alternate

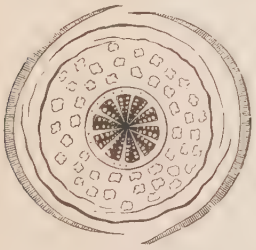

FIG. 313.—Transverse section of flower of Poppy. (*Sayre.*)

FIG. 314.—Gynœcium of Poppy, with one stamen remaining. (*Sayre.*)

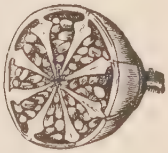

FIG. 315.—Transverse section of ovary of Poppy. (*Sayre.*)

and more or less compound. Inflorescence a raceme or spike. Flowers irregular, hermaphrodite, zygomorphic; sepals 2, petals 4,

the two outer often saccate or with a spur at the base; stamens 4 or 6; ovary superior, 1-celled with 2 parietal placentas. Fruit a one-chambered capsule. Seeds albuminous. Idioblasts common.

Official drug	Part used	Botanical name	Habitat
Corydalis	Tubers	Dicentra canadensis Dicentra Cucullaria	United States and Canada

Cruciferæ or Mustard Family.—Herbs, rarely shrubs, mostly of temperate regions. Stem and branches upright or diffuse spreading

FIG. 316.—*Brassica nigra*—Branch. (*Sayre.*)

(*Arabis*). Leaves alternate, simple, rarely compound, exstipulate, entire or toothed, often more or less hairy. Inflorescence at first a corymb or shortened raceme, later elongating into a loose raceme. Bracts at base rarely reduced, usually absent. Flowers regular—

rarely irregular (Candytuft)—tetramerous. Sepals four, green, equal, or two laterals at times pouched as nectar receptacles. Petals four, yellow, white, pink or purple, cruciform, often divisible into claw and blade. Stamens six, four being long and anteroposterior in position, two being short and lateral, hence termed tetradynamous, insertion hypogynous. Pistil syncarpous, bicarpellate, superior, carpels lateral. Ovary one-celled but falsely two-celled by a placental replum (a spurious membranous partition); style simple; stigma rounded or bifid or bilobed. Ovules several, rarely few, attached to marginal placenta. Fruit a siliqua or silicule rarely indehiscent—bursting lengthwise by two valves. Seeds exalbuminous with folded cotyledons.

Official drug	Part used	Botanical name	Habitat
Oleum Sinapis Volatile	Volatile oil	Brassica nigra Brassica juncea	Europe and Asia Asia
Sinapis Nigra	Seed	Brassica nigra Brassica juncea	Europe and Asia Asia
Unofficial drug			
Semen Rapæ	Seed	Brassica napus	Europe and Asia
Armoracia	Root	Cochlearia Armoracia	Europe
Sinapis Alba	Seed	Sinapis alba	Europe and Asia

ORDER SARRACENIALES

This order includes several families of plants whose leaves are modified for the purpose of catching and digesting insects. The principal families are the *Sarraceniaceæ* and *Nepenthaceæ* both of which have their leaves modified as pitchers, and the *Droseraceæ* which includes the Fly-Traps and Sundews.

Droseraceæ or Sundew Family.—Herbs (*Drosera*, *Dionaea*, etc.) rarely shrubs (*Roridula* of South Africa), growing in bogs or swamps or purely aquatic in habit (*Aldrovanda*). Leaves, either rosettes or more or less scattered in alternate fashion over stem, usually glandular-hairy or sensitive-hairy and insectivorous. Inflorescence a loose raceme or cymose umbel. Flowers regular, pentamerous; sepals five, aposepalous, green; petals apopetalous, varying from white to whitish-pink, pink, scarlet, purple to bluish-purple; stamens

varying from fifteen to five, hypogynous; pistil syncarpous of five to three, rarely fewer carpels. Fruit a capsule. Seeds albuminous.

Official drug	Part used	Botanical origin	Habitat
Drosera	Entire plant	Drosera rotundifolia Drosera anglica Drosera longifolia	Eastern and western Hemispheres

FIG. 317.—*Drosera rotundifolia*. Production of a young plant from the leaf of an older plant. (*Gager.*)

ORDER ROSALES

Saxifragaceæ or Saxifrage Family.—Herbs (Mitrewort (*Mitella*), Saxifrage (*Saxifraga*), Alum-root (*Heuchera*), etc.) or shrubs (*Hydrangea, Philadelphus* or Mock-orange, etc.) rich in tannin content, with opposite or alternate leaves usually devoid of stipules. Flowers regular, hermophrodite; sepals 5 usually, petals 5 to 10, sometimes absent, petals and stamens perigynous to epigynous; ovary 3 to 1 celled, free or adnate to upgrown receptacle. Fruit a follicle, capsule, or berry. Seeds small with copious albumen and tiny embryo.

Official drug	Parts used	Botanical name	Habitat
Hydrangea	Rhizome and roots	Hydrangea arborescens	United States
Unofficial drug			
Heuchera	Root	Heuchera americana	United States

FIG. 318.—*Liquidambar orientalis*—Branch. (*Sayre.*)

Hamamelidaceæ or Witch Hazel Family.—Shrubs or small or large trees. Leaves, simple, alternate and pinnately veined; stipules deciduous to caducous, paired and slightly fused at the bases of petioles. Flowers frequently yellow to yellowish-white, in axillary clusters or heads or spikes, hermaphrodite or monœcious; sepals and petals five to four, rarely indefinite, superior (petals absent in

FIG. 319.—*Hamamelis virginiana.* Upper figure shows this shrub as it appears in autumn after the leaves have fallen. Note that the plant is in blossom. Lower figure shows a flowering branch from the same plant. The bright yellow flowers [illegible] fruits from blossoms of the previous year.

Fothergilla); stamens twice as many as the petals, but the outer row alone fertile, the inner row being more or less barren, scale-like; gynœcium of two carpels united below. Fruit a two-beaked, two-celled, woody capsule dehiscing at the summit, with a bony seed in each cell, or several, only one or two of them ripening.

Official drug	Part used	Botanical name	Habitat
Styrax	Balsam from wood and inner bark	Liquidambar orientalis	The Levant
		Liquidambar Styraciflua	Central America
Hamamelidis Folia	Leaves	Hamamelis virginiana	United States and Canada

Rosaceæ or Rose Family.—Herbs, shrubs, or trees mostly of temperate regions. Stem and branches upright or creeping (Strawberry, Cinquefoil), herbaceous to woody. Leaves alternate, stipulate (stipules green, persistent to scaly, deciduous), compound, condensing to "simple." Flowers regular, pentamerous; sepals and petals 5, rarely 4, inferior to ovary, becoming by stages superior to it. Sepals green, at times with epicalyx (Strawberry, Cinquefoil, etc.), persistent round fruit. Petals usually yellow to white or pink, crimson, rarely purple, rosaceous, deciduous. Stamens indefinite, perigynous (Strawberry, etc.), to semi-epigynous (Rose, Peach, etc.), and epigynous (Apple, Pear, Quince). Pistil apocarpous with many (Strawberry, Rose) carpels or fewer to five (Apple), or two to one (Plum, Cherry), becoming falsely fused by union with upgrowing receptacle (Hawthorn, Quince, Pear, Apple). Fruit a collection of achenes on dry (Cinquefoil) or succulent receptacle (Strawberry), or dry follicles (Bridal Wreath), or drupels (Blackberry), or a drupe (Peach, Plum, Cherry), or a pome (Apple, Quince, Pear). Seeds exalbuminous, embryo filling seed cavity.

Some botanists divide this family into three sub-families, each of which, in the American System, has been given the rank of a family. These according to this system of classification are: *Rosaceæ*, *Malaceæ* and *Amygdalaceæ*. Rosaceæ include the genera *Geum*, *Agrimonia*, *Duchesnia*, *Fragaria*, *Potentilla*, *Waldsteinia*, *Cercocarpus*, *Spiræa*, *Rubus*, *Dalibarda* and *Rosa*.

Malaceæ include the genera *Sorbus* (Mt. Ash), *Malus* (Crab Apple and Apple), *Amelanchier* (Service Berry and Shad Bush), *Pyrus* (Pear), *Aronia* (Choke Berry), *Crategus* (Hawthorn) and *Cotoneaster* (Christ's Thorn).

FIG. 320.—*Quillaja saponaria*—Branch. (*Sayre.*)

Amygdalaceæ comprise the genera *Prunus* (Plum group), *Padus* (Wild Cherry group) and *Amygdalus* (Almond and Peach group).

Official drug	Part used	Botanical name	Habitat
Prunus Virginiana	Bark	Prunus serotina	United States and Canada

Official drug	Part used	Botanical name	Habitat
Rubus	Bark of rhizome and roots	Sect. Eubatus of genus Rubus	United States
Quillaja	Inner bark	Quillaja Saponaria	Chile and Peru
Brayera	Panicles of pistillate flowers	Hagenia abyssinica	Abyssinia
Rosa	Petals	Rosa gallica	W. Asia and S. Europe
Rubi Fructus	Fresh ripe fruit	Rubus nigrobaccus and Rubus villosus	United States

FIG. 321.—*Prunus domestica*—Fruiting branch and flowering branch. (*Sayre.*)

Succus Pomorum	Juice of Fruit	Pyrus Malus (cultiv. var's.)	Europe
Rubi Idæi Fructus	Juice of Fruit	Rubus Idæus and Rubus strigosus	Europe and Asia
Prunum	Fruit	Prunus domestica	Southwestern Asia
Oleum Amygdalæ Amaræ	Vol. oil from kernels	Amygdalus communis	W. Asia
Oleum Amygdalæ Expressum	Fixed oil	Amygdalus communis (var's.)	W. Asia

Unofficial drug	Part used	Botanical name	Habitat
Oleum Rosæ	Vol. oil	Rosa damascena	Balkans
Amygdala Dulcis	Seed	Amygdalus communis var. dulcis	W. Asia
Amygdala Amara	Seed	Amygdalus communis	W. Asia

FIG. 322.—*Glycyrrhiza glabra*—Branch. (*Sayre.*)

Folia Laurocerasi	Leaves	Prunus Laurocerasus	Asia Minor, Persia
Cydonium	Seed	Cydonia vulgaris	Cultivated widely
Rosa Centifolia	Petals	Rosa centifolia	Western Asia
Rosa Canina	Spurious Fruit	Rosa canina	Europe
Tormentilla	Rhizome	Potentilla silvestris	Europe and Asia

Leguminosæ or Pea Family (*Fabaceæ*).—Herbs, shrubs or trees of all regions, with tubercled roots. Stem usually erect, rarely creeping (*Trifolium repens*). Leaves alternate, compound—rarely simple—stipulate, sometimes tendriliform or reduced to phylloid petioles (*Acacia sp.*). Inflorescence a raceme, at times, condensed almost to a head or capitulum (Sp. of clover, *Mimosa*, etc.). Flowers pentamerous (rarely four), regular (*Mimosaceæ*), to irregular (*Cæsalpinaceæ*) to very irregular with corolla butterfly-shaped (*Papilionaceæ*). Sepals five united, green; petals five (rarely four) variously related, in *Papilionaceæ* one superior, external, posterior—standard or vexillum, two lateral form wings or alæ, two

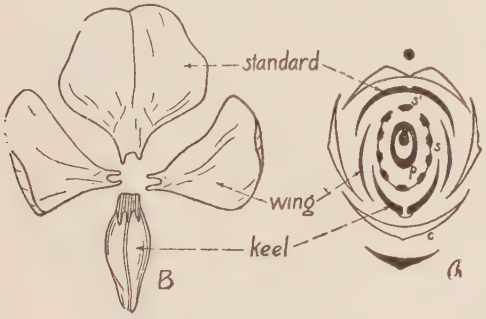

FIG. 323.—Flower of Papilionaceæ. *A*, floral diagram of *Vicia faba; B*, sweet pea flower, dissected, diagrammatic. (*From Robbins, A after Eichler, B after Bergen and Caldwell.*)

inferior internal and anterior, slightly adherent, form keel. Stamens ten to four, free or in *Papilionaceæ* united by filaments into a monadelphous (ten) or a diadelphous (nine to one) tube, inserted perigynously. Pistil typically monocarpellary, ovary with sutural placentation, style simple. Fruit a legume, more rarely becoming transformed into a lomentum by transverse constrictions (*Entada scandens*). Seeds exalbuminous.

There are three natural subdivisions of the Leguminosæ: (1) The *Mimosaceæ* or *Mimosa* alliance is characterized by possessing regular flowers, often in capitula, the petals of which do not overlap or are they overlapped, and by often furnishing mucilage. To this group belong the plants yielding Acacia and Catechu. (2) The

Cæsalpinaceæ which have slightly irregular flowers, the petals of which are imbricate in aestivation, the odd posterior petal in the flower being overlapped by the 2 side petals. To this group belong the plants yielding Copaiba, Hæmatoxylon, Senna, Cassia Fistula and Tamarindus. (3) The *Papilionaceæ* which have very

Fig. 324.—*Cassia Senna*—Branch showing flower and fruit. (*Sayre.*)

irregular flowers, the petals of which are imbricate in aestivation, but the odd petal here called the standard, overlaps the 2 side petals and the two side petals overlap the keel petals. To this group belong the plants yielding Tolu, Balsamum Peruvianum, Baptisia, Glycyrrhiza, Goa Powder, Foenugreek, Galega, Melilotus, Trifolium, Tragacantha, Tonka, Santalum Rubrum, Scoparius, Physostigma, etc.

Official drug	Part used	Botanical name	Habitat
Acacia	Gummy exudation	Acacia Senegal and some other species of Acacia	Africa
Tragacantha	Gummy exudation	Astragalus gummifer and other Asiatic species	Asia
Balsamum Peruvianum	Balsam	Toluifera Pereiræ (Myroxylon Pereiræ)	Central America
Tolu	Balsam	Toluifera Balsamum	Northern South America
Hæmatoxylon	Heartwood	Hæmatoxylon campechianum	Central America
Santalum Rubrum	Heartwood	Pterocarpus santalinus	Indo-China and S. India
Glycyrrhiza	Rhizome and roots	Glycyrrhiza glabra var. typica; Glycyrrhiza glabra var. glandulifera and other var's. of G. glabra yielding a yellow and sweet wood	S. Europe, W. and C. Asia
Senna	Leaflets	Cassia Senna; Cassia angustifolia	Egypt and the Soudan; Arabia and Africa
Cassia Fistula	Fruit	Cathartocarpus Fistula	India
Tamarindus	Pulp of fruit	Tamarindus indica	Tropical Africa
Copaiba	Oleoresin	Copaiba species	South America
Chrysarobinum	Neutral principle	Vouacapoua Araroba	Brazil
Kino	Inspissated juice	Pterocarpus Marsupium	India
Scoparius	Tops	Cytisus scoparius	Europe
Trifolium	Inflorescence	Trifolium pratense	Europe
Galega	Flowering herb	Galega officinalis	S. Europe and W. Asia
Baptisia	Root	Baptisia tinctoria	Eastern United States and Canada
Krameria	Root	Krameria triandra	Peru and Bolivia
		Krameria argentea	Brazil

Official drug	Part used	Botanical name	Habitat
Melilotus	Leaf and flowering top	Melilotus officinalis	Europe
Physostigminæ Salicylas	Salicylate of alkaloid from seed	Physostigma venenosum	Africa
Unofficial			
Physostigma	Seed	Physostigma venenosum	Africa
Mesquite Gum	Gum	Prosopis juliflora	Mexico
Fenugreek	Seed	Trigonella Fœnum-græcum	Mediterranean region
Piscidia	Bark	Piscidia Erythrina	West Indies
Indigo	Coloring matter	Indigofera tinctoria	India
Soy Bean	Seed	Glycine hispida	United States and Europe
Abrus	Seed	Abrus precatorius	Tropics and subtropics
Catechu	Extract	Acacia Catechu	India
Mucuna	Hairs from fruits	Mucuna pruriens	East and West Indies

ORDER GERANIALES OR GRUINALES

Geraniaceæ or Geranium Family.—Herbaceous, rarely semi-succulent, sub-shrubby plants. Stems cylindrical, often hairy or glandular hairy. Leaves alternate to opposite, stipulate; venation from pinnate to palmate, so leaf shape from ovate to pinnatifid to pinnatipartite to sub-palmatifid to palmatipartite to compound palmate. Inflorescence either a dichesial or scorpioid cyme. Flowers regular, pentamerous (*Geranium*) to irregular pentamerous (*Pelargonium*); sepals five, aposepalous; petals five, apopetalous, varying in color from greenish-white or pink-red to scarlet, scarlet-crimson to crimson-purple; stamens with anthers ten or five, hypogynous or inserted into slightly developed hypogynous disk; pistil pentacarpellary, ovary five-celled with two, rarely one ovule in each cell, styles elongate, fused round a stylar column of receptacle then continued as a stylar tip which splits into five stigmatic surfaces. Fruit a regma, rarely a simple capsule. Regma splits into five recurved carpels, each then dehiscing to set free two or one seeds. Seeds exalbuminous.

Official drug	Part used	Botanical name	Habitat
Geranium	Rhizome	Geranium maculatum	North America
Unofficial			
Oil of Rose Geranium	Volatile oil	Pelargonium odoratissimum Pelargonium Radula Pelargonium capitatum	Mediterranean regions

FIG. 325.—*Physostigma venenosum.*—Portion of plant and fruit. (*Sayre.*)

Linaceæ or Flax Family.—Herbs with slender stems and alternate, simply, narrow leaves. Inflorescence cymose with regular pentamerous flowers; pistil five-carpelled with a five-celled ovary

containing two ovules in each cavity and having a single style with a knob-like stigma. While the flower is still in bud condition or soon after, there commences an ingrowth of the mid-rib of each carpel which proceeds until, when plant is in fruit, there are formed 10 cavi-

FIG. 326.

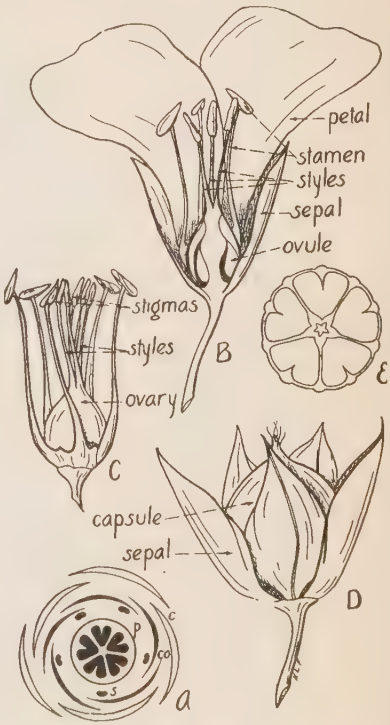

FIG. 327.

FIG. 326.—*Linum usitatissimum.* (*Sayre.*)

FIG. 327.—Flax. *A*, floral diagram—*c*, calyx; *co*, corolla; *s*, stamens; *p*, pistil, *B*, median lengthwise section of flower. *C*, calyx and corolla removed. *D*, fruit, external view. *E*, cross-section of fruit. (*Robbins.*)

ties each enclosing a seed. Seeds, anatropous, mucilaginous, flattened, containing a large embryo and slight albumen.

Official drug	Part used	Botanical name	Habitat
Linum	Seeds	Linum usitatissimum	Unknown. Cult. in
Oeum Lini	Fixed oil	Linum usitatissimum	Temperate regions

Erythroxylaceæ or Coca Family.—Shrubs (*Erythroxylon*) or trees with alternate, simple, entire, glabrous and pinnately veined leaves. Flowers regular, hermaphroditic, each with five sepals, five hypogynous petals, ten stamens and a two- to three-celled ovary subtending three styles, each with a capitate stigma. Fruit an ovoid, angular, one celled drupe containing a single seed.

FIG. 328.—*Guajacum sanctum*—Flowering branch. (*Sayre.*)

Official drug	Part used	Botanical origin	Habitat
Cocaina Cocainæ Hydrochloridum	Alkaloid Hydrochloride of alkaloid	Erythroxylon Coca and other species of Erythroxylon	Peru and Bolivia, South America
Unofficial			
Coca	Leaves	Erythroxylon Coca and E. truxillense	Peru and Bolivia

Zygophyllaceæ or Caltrop Family.—Herbs, shrubs or trees (*Guajacum*) having jointed, often divaricate branches. Leaves usually opposite, stipulate and compound. Flowers regular or irregular, pentamerous, white, yellow, red or blue (*G. officinale*). Fruit a capsule.

FIG. 329.—*Citrus Aurantium*—Branch. (*Sayre.*)

Official drug	Part used	Botanical origin	Habitat
Guaiacum	Resin of wood	Guajacum officinale Guajacum sanctum	W. Indies and S. America
Unofficial drug			
Guaiaci Lignum	Heartwood	G. officinale and G. sanctum	W. Indies and S. America

Rutaceæ or Rue Family.—Herbs (*Rue*), shrubs (*Jaborandi* and *Buchu*) or trees (*Orange, Lemon, Grape Fruit,* etc.). Stems upright,

often wiry and xerophytic in the Rue sub-family or *Ruteæ*, elongated and spiny in the Prickly Ash sub-family or *Zanthoxyleæ*, woody and green in the Citrus sub-family or *Aurantieæ*. Leaves alternate or opposite, simple (*Ruta*), rarely whorled (*Pilocarpus*) or pinnatifid, as in the Rue plant (*Ruta graveolens*), or pinnate, as lower parts of *Ruta graveolens*, becoming reduced pinnate in the Orange (*Citrus Aurantium*). Leaves exstipulate or with spiny stipules (*Zanthoxylum*). Stems and leaves abound in more or less sunken glands. Flowers pentamerous, varying in color from yellow in *Ruta* to white in *Citrus* to pink (*Barosma betulina*) or pink crimson, as in some *Barosma* and *Diosma* species, rarely to pinkish-purple (*Pilocarpus*); sepals five, aposepalous, becoming in *Citrus* more or less synsepalous; petals five, apopetalous, becoming more or less synpetalous and tubular (*Correa grandiflora*); stamens five, simple or with expanded bases, lobed, or lobes developed as staminal stipules and more or less split (*Citrus*); pistil of ten, five, three or two carpels, ovary as many-celled, with frequently 2 to 1 ovules in each cell. Fruit a capsule (*Dittany*, *Zanthoxylum*), berry (*Citrus*) or rarely a samara, as in the Wafer Ash (*Ptelea*). Seeds albuminous or exalbuminous. Many of the plants contain volatile oils in their secretory cavities.

FIG. 330.—*Barosma betulina* Branch and flower. (*Sayre.*)

Official drug	Part used	Botanical origin	Habitat
Aurantii Dulcis Cortex	Outer rind of ripe fruit	Citrus Aurantium var. sinensis	Northern India
Oleum Aurantii	Vol. oil from fresh peel of fruit	Citrus Aurantium var. sinensis	Northern India

Official drug	Part used	Botanical origin	Habitat
Aurantii Amari Cortex	Rind of fruit	Citrus Aurantium	Northern India
Limonis Cortex	Outer rind of ripe fruit	Citrus medica var. Limonum	Northern India
Oleum Limonis	Vol. oil from fresh fruit peel	Citrus medica var. Limonum	Northern India
Pilocarpinæ Nitras	Nitrate of alkaloid from leaflets	Pilocarpus Jaborandi	Brazil
Pilocarpinæ Hydrochloridum	Hydrochloride of alkaloid from leaflets	Pilocarpus microphyllus	Brazil
Buchu	Leaves	Barosma betulina, B. crenulata and B. serratifolia	S. Africa
Xanthoxylum	Bark	Zanthoxylum americanum	Northern United States
		Zanthoxylum Clava-Herculis	Southern United States
Oleum Bergamottæ	Volatile oil from fresh fruit rind	Citrus Aurantium var. Bergamia	France, Italy
Oleum Aurantii Florum	Volatile oil from fresh flowers	Citrus Aurantium	Northern India
Oleum Aurantii Amari	Volatile oil from fresh peel	Citrus Aurantium	Northern India
Xanthoxyli Fructus	Capsules	Zanthoxylum americanum	Northern United States
		Zanthoxylum Clava-Herculis	Southern United States
Unofficial			
Ruta	Leaves	Ruta graveolens	Southern Europe
Ptelea	Bark of root	Peltea trifoliata	North America
Belæ Fructus	Unripe fruit	Ægle Marmelos	Malabar, Coromandel

Simarubaceæ or Ailanthus Family.—A family of chiefly tropical shrubs or trees containing bitter principles. The leaves are mostly alternate and pinnate. The flowers are unisexual or polygamous and arranged in axillary panicles (*Picrasma excelsa*) or in terminal racemes (*Quassia amara*). The fruit is a drupe (*Picrasma*) or pod

(*Quassia*). The plants are distinguished from those of the *Rutaceæ* by the absence of secretory cavities.

FIG. 331.—Branch of a Quassia yielding plant, *Picrasma excelsa*. Note the imparipimate leaves and axillary flower clusters. (*After Sayre.*)

Official drug	Part used	Botanical origin	Habitat
Quassia	Wood	Picrasma excelsa	West Indies
		Quassia amara	Surinam
Cascara Amarga	Bark	Picramnia Sp.	Mexico and C. America

Unofficial	Part used	Botanical origin	Habitat
Simaruba	Bark of root	Simaruba officinalis	South America
		Simaruba amara	Central America, Bahamas and Florida

Burseraceæ or Myrrh Family.—Shrubs and trees of tropical climes having secretion reservoirs in their bark which contain gum-resin

FIG. 332.—*Commiphora myrrha*—Branch. (*Sayre.*)

or oil. Leaves alternate, exstipulate and compound (trifoliate in *Commiphora Myrrha*). Flowers small, regular and hermaphrodite, arranged in racemes or panicles. Fruit a drupe.

Official drug	Part used	Botanical origin	Habitat
Myrrha	Gum resin	Commiphora species	East Africa and Arabia
Unofficial			
Olibanum	Gum resin	Boswellia carterii	East Africa and Arabia

Meliaceæ or Mahogany Family.—Tropical trees or shrubs with wood often hard, colored and odoriferous. Leaves alternate, exstipulate, pinnately-compound, rarely simple and entire. Inflorescence a terminal or axillary raceme. Flowers hermaphrodite or rarely polygamo-diœcious, regular; sepals five to four, small; petals usually five to four, hypogynous; stamens generally ten to eight rarely five, very rarely twenty to sixteen, inserted outside the base of the hypogynous disc; filaments united into a tube; carpels usually five to three; style simple; ovary free, usually five- to three-celled. Fruit a drupe (*Melia*), berry (*Vavaea*), or capsule (*Cedrela*). Seeds exalbuminous or with fleshy albumen.

Official drug	Part used	Botanical origin	Habitat
Cocillana	Bark	Guarea Rusbyi	Bolivia

Polygalaceæ or Milkwort Family.—Herbs or shrubs with upright, herbaceous to woody stems often branching profusely, the branches occasionally becoming geotropic or subterranean and bearing cleistogamous flowers. Leaves simple, often lanceolate or linear, exstipulate, alternate. Inflorescence a raceme, spike (*Polygala Senega*) or head (*P. lutea*). Flowers irregular, hermaphroditic with 5 distinct sepals, the 2 lateral ones being large and petaloid, 5 petals of which the two lateral are wanting or rudimentary and the anterior large and boat-shaped, eight stamens, and a bicarpellate pistil. Fruit a two-celled capsule (*P. Senega*), rarely a drupe or samara. Pollen grains barrel-shaped.

Official drug	Part used	Botanical origin	Habitat
Senega	Root	Polygala Senega	United States and Canada

Euphorbiaceæ or Spurge Family.—Often herbaceous, more rarely shrubby, rather seldom arborescent plants. Stem, leaves and other

parts in several genera traversed by latex canals that are either ramifying cells (*Euphorbia*) or laticiferous vessels (*Manihot*, *Hevea*, etc.) or rows of laticiferous sacs (*Micrandra*) and contain a white

FIG. 333.—*Polygala senega*—Plant and rhizome. (*Sayre.*)

latex with acrid often poisonous contents or alkaloid or hydrocarbon, at times, rubber contents. Leaves alternate, exstipulate to stipulate, simple to pinnate or palmate. Inflorescence cymose. Flowers

usually, as in *Ricinus*, etc., pentamerous, monœcious; sepals five, green, aposepalous, becoming rudimentary or absent in *Euphorbia*. Petals none or five more or less petaloid; stamens numerous to ten

Fig. 334.—The Castor Oil plant (*Ricinus communis*). (*From Strasburger after Baillon.*)

to five or one (*Euphorbia*); pistil in pistillate flowers rarely of twenty to ten apocarpous or loosely syncarpous carpels (Sandbox tree), commonly of three syncarpous carpels with distinct radiate styles; ovary as many-celled as carpels with two to one ovules in each cell.

Fruit a tricoccoid regma or capsule, rarely winged, indehiscent, nut-like. Seeds with oily endosperm. Flowers at times surrounded and subtended by more or less petaloid and expanded bracts and bracteoles.

Official name	Part used	Botanical origin	Habitat
Euphorbia	Herb	Euphorbia hirta	India
Stillingia	Root	Stillingia sylvatica	Southern United States
Oleum Ricini	Fixed oil	Ricinus communis	India
Oleum Tiglii	Fixed oil	Croton Tiglium	Asia
Unofficial			
Tapioca	Starch	Manihot utilissima	South America
Kamala	Hairs of capsule	Mallotus philippinensis	Asia
Elastica	Prepared latex	Hevea braziliensis and other species	Brazil
Cascarilla	Bark	Croton Eluteria	West Indies

ORDER SAPINDALES

Anacardiaceæ or Sumac Family.—Shrubs or trees producing in stems and leaves secretion contents that are either acrid-watery or acrid-opalescent or white-viscid, viscid-acrid and poisonous. Leaves alternate, rarely opposite, simple (*Rhus Cotinus*), three foliate (*Rhus toxicodendron*) or pinnate (*Rhus glabra*, *R. venenata*, etc.). Inflorescence frequently terminal and composed of racemes of cymes, often reduced to a simple raceme. Flowers small, clustered, green, greenish-white to greenish-yellow; sepals five, rarely six or four green, small; petals five, smaller than sepals; stamens equal in number to the petals and alternate, rarely fewer, sometimes double in number, rarely indefinite, inserted hypogynously or upon an enlarged disc that surrounds or swells up between stamens and pistil; pistil monocarpellary (*Rhus*), more rarely bicarpellary, very rarely, as in *Spondieæ*, of ten to five carpels, ovary one-celled with single ovule. Fruit a drupe. Seeds exalbuminous with large embryo filling seed cavity.

Official drug	Part used	Botanical origin	Habitat
Rhus Glabra	Ripe fruits	Rhus glabra	Canada and United States
Mastiche	Concrete resinous exudate	Pistacia Lentiscus	Grecian Archipelago
Unofficial			
Chinese Galls	Excrescences	Rhus semialata	China
Japanese Galls	Excrescences	Rhus japonica	Japan
Rhus Typhina	Ripe fruits	Rhus typhina	United States
Acajou Gum	Gum	Anacardium occidentale	West Indies
Pistachio	Seeds	Pistacia vera	Western Asia
Anacardium	Fruit	Anacardium occidentale	West Indies
Rhus Toxicodendron	Fresh leaflets	Rhus toxicodendron	United States

Aquifoliaceæ (*Ilicaceæ*) *or Holly Family.*—Trees or shrubs, chiefly evergreen; leaves alternate, petiolate, simple with entire to spiny-toothed margin (*Ilex opaca* or American Holly). Flowers regular, small, greenish to white, hermaphrodite or polygamous or diœcious. Fruit drupaceous and containing 4 to 6 nutlets. Caffeine has been obtained from Maté and Cassena.

Unofficial drug	Part used	Botanical name	Habitat
Maté	Leaves	Ilex paraguayensis	South America
Cassine (Cassena)	Leaves	Ilex vomitoria	Southeastern United States
Black Alder (Prinos)	Bark	Ilex verticillata	North America

Celastraceæ or Staff Tree Family.—Shrubs (*Evonymus*), or shrubby climbers (*Celastrus*). Leaves rarely alternate (*Celastrus*) usually opposite (*Evonymus, Pachystima*), simple, entire or toothed. Inflorescence of axillary cymes of terminal racemes. Flowers perfect (*Evonymus, Pachystima*) or polygamo-diœcious (*Celastrus*), greenish (*Celastrus*), greenish or yellowish-white (*Evonymus Europæus*), greenish-purple (*Evonymus americanus*) to dark purple (*Evonymus atropurpureus*); calyx four- to five-lobed; corolla of four to five petals; stamens four to five, perigynous, on a disc, which fills the base of the calyx and sometimes covers the ovary; ovary three- to five-celled. Fruit a two- to five-celled capsule. Seeds albuminous

with fleshy reddish aril (*Evonymus, Celastrus*) or white membranous aril (*Pachystima*).

Official drug	Part used	Botanical origin	Habitat
Euonymus	Bark of root	Evonymus atropurpureus	United States

FIG. 335.—*Evonymus atropurpureus.* Flowering branch to left; fruiting branch to right.

Sapindaceæ or Soapwort Family.—Trees (*Sapindus*), shrubs (*Paullinia*), undershrubs or rarely herbaceous vines of tropical climes (*Cardiospermum*) containing the glucoside saponin. Stem

erect or climbing (*Paullinia*) often provided with tendrils. Leaves commonly alternate and compound. Flowers in racemes or panicles (*Paullinia*) or corymbs (*Cardiospermum*), perfect or polygamo-diœcious, yellowish in *Paullinia Cupana*. Fruit a capsule (*P Cupana*), samara, drupe or berry (*Sapindus*). Seeds exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Guarana	Dried Paste, made from crushed seed	Paullinia Cupana	Brazil

Aceraceæ or Maple Family.—Chiefly trees, occasionally shrubs, of temperate regions with watery sap. Leaves opposite, simple and palmately lobed or cleft (*Acer*) or pinnate (*Negundo*). Inflorescence a raceme, condensing in some species to a capitulum of cymes. Flowers small, regular, polygamous or diœcious; sepals five to four, green; petals none or five, variously colored; stamens usually eight, hypogynous or perigynous; nectar disc around stamens or between them and pistil; pistil bicarpellary with two-celled ovary. Fruit a samara. Seeds green, exalbuminous with coiled or folded embryo and long thin cotyledons.

Unofficial drug	Part used	Botanical origin	Habitat
Acer Spicatum	Bark	Acer spicatum	United States

ORDER RHAMNALES

Rhamnaceæ or Buckthorn Family.—Shrubs or low trees usually of branching or spreading habit. Branches either cylindric or long green or hardened, checked back and spinescent, occasionally, especially flowering branches, developing tendrils for support. Leaves simple, usually alternate and stipulate. Inflorescence cymose. Flowers hermaphrodite or more or less diclinous, pentamerous to tetramerous, greenish to greenish-yellow to yellowish-white; sepals five to four; petals five to four alternating with sepals; stamens five opposite the petals, perigynous; pistil either free in center of receptacular cup or more or less fused with it and so semi-inferior, ovary typically three-celled becoming rarely four-celled with two to one atropous ovules in each cavity. Fruit of three

indehiscent cocci, each enclosing a single albuminous seed with straight embryo imbedded in albumen.

FIG. 336.—*Rhamnus Frangula*—Branch. (*Sayre.*)

Official drug	Part used	Botanical origin	Habitat
Cascara Sagrada	Bark	Rhamnus Purshiana	Northern California, Oregon, Washington, and southwestern British America
Frangula	Bark	Rhamnus Frangula	Europe
Rhamnus Cathartica	Fruit	Rhamnus cathartica	Asia and Africa

Vitaceæ or Grape Family.—Rarely tall, herbaceous, usually shrubby and climbing, more rarely shrubby, upright plants. Stems rarely short, more usually elongate, feeble, rather brittle, climbing by tendrils which represent modified inflorescence shoots. Leaves alternate, simple to lobed (either pinnately or more often palmately) to compound-pinnate or palmate. Perfect graded series of lanceolate leaves with pinnate veining to palmate veining; from pinnately veined to compound-pinnate; from palmately veined to compound-palmate. Stipules greenish to membranous or none. Flowers in racemes of compressed cymes, hermaphrodite or diclinous, nearly always small, clustered, green to greenish-yellow or greenish-white, rarely otherwise; sepals five, rarely four, small to minute (mere rim of receptacle) more or less persistent. Petals five, deciduous to caducous, typically distinct (in *Vitis*), united by their tips into calyptroform corolla, so in June, as Grape Vine flowers expand, corolla splits at base into five lobes that separate below, being attached at tips, while whole becomes tumbled off by lengthening stamens. Pistil bicarpellate. Ovary two-celled, superior or at most subinferior. Ovules two to one, erect. Style short, often more or less thickened, with terminal, capitate, slightly two-lobed stigmas. Stamens equal to petals or sepals and opposite petals. Receptacle internal to stamens, often expanded into nectariferous girdle or, in *Vitis*, into receptacular knobs alternating with stamens. Fruit a berry rarely six- to three-celled, typicaly two-celled and with two to one seeds in each cavity. Seeds like ovules, erect with bony testa. Embryo small, imbedded at base of cartilaginous albumen.

Brandy or Spiritus Vini Vitis U.S.P. is an alcoholic liquid obtained by the distillation of the fermented juice of sound, ripe grapes and containing from 48 to 54 per cent. of ethyl alcohol.

ORDER MALVALES

Sterculiaceæ or Cola Family. -Rarely herbs, usually shrubs or tall, often heavy trees with soft wood and broad annual rings. The cambium, in developing bast, produces one, two, three, four, or five alternating layers of hard and soft bast which in some species of this as well as the *Tiliaceæ* or Linden family form long finger-like proc-

FIG. 337.—*Theobroma Cacao*, the Chocolate plant. 1. Trunk and branches bearing fruit. 2. Branch bearing flowers. 3. Single flower. 4. Staminal ring. 5. Stamen. (*After Strasburger, Noll, Schenck and Schimper.*)

esses pushing out into the cortex. Leaves alternate, sometimes simple and pinnately-veined or passing to palmately-veined or palmately-compound. Flowers hermaphrodite; sepals five, sometimes surrounded by bracteoles forming an epicalyx; petals usually five; stamens typically five, hypogynous, opposite petals, distinct or slightly fused in monadelphous fashion (*Melochia, Waltheria*) or, stamens subdivided above into few or numerous staminal leaflets, anthers two-celled; pistil many- to ten- to five- or four-carpelled; carpels apocarpous or more usually partially or completely united. Fruit either follicles, or fused to form a capsule of ten or more, frequently five dehiscent carpels or, carpels splitting asunder into cocci or, becoming a woody capsular nut (*Theobroma*) or, rarely the fruit may become succulent. Seeds globose or subglobose and often provided with wings, arils or similar appendages; embryo straight, large and surrounded by scanty albumen.

Official drug	Part used	Botanical origin	Habitat
Oleum Theobromatis	Fixed oil	Theobroma Cacao	Tropical America
Cacao Præparatum	Prepared powder from roasted, cured kernels of seeds	Theobroma Cacao and other species	Tropical America
Kola	Cotyledons	Cola nitida and other species	Africa

Tiliaceæ or Linden Family.—Shrubs or trees, rarely herbs, having stellate hairs on both stems and leaves. Leaves alternate, pinnately more rarely palmately veined, stipulate. Inflorescence cymose. Flowers hermaphrodite, more rarely, by absorption, more or less diclinous; sepals and petals five each, more rarely four, sepals deciduous; stamens five opposite the petals or, as in *Sterculiaceæ*, five phalanges of stamens representing subdivided stamens (*Tilia*), pistil of ten to five or two syncarpous carpels; ovary superior. Fruit either a nut-like drupe or drupe, rarely baccate.

Unofficial	Part used	Botanical origin	Habitat
Tilia (Linden flowers)	Inflorescence	Tilia species	United States and Europe

Malvaceæ or Mallow Family.—Herbs in temperate regions (*Malva rotundifolia*, *Althæa officinalis*, etc.), occasionally shrubs in temperate regions (*Hibiscus Syriacus or Rose of Sharon*, etc.), frequently shrubs or tall trees in the tropics. Stems, as in *Sterculiaceæ* and *Tiliaceæ*, sometimes forming numerous layers of hard and soft bast. Leaves

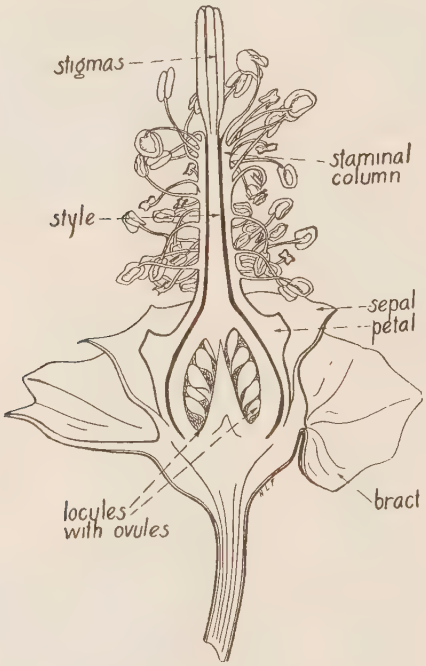

Fig. 338.—Median lengthwise section through flower of Upland Cotton (*Gossypium hirsutum*) × 2. (*After Robbins.*)

alternate and stipulate, ovate, ovate-cordate, orbicular or palmately-compound; venation pinnate or palmate. Stems, roots and leaves contain mucilage cells. Inflorescence a raceme or fascicle of cymes. Flowers regular, pentamerous; calyx green, of five aposepalous sepals but frequently surrounded outside by an epicalyx. Both calyx and epicalyx are persistent. Corolla of five petals, varying in color;

which are more or less fused with stamens at their bases, stamens monadelphous and forming an upright column (*staminal column*) enclosing the styles; anthers one-celled, dehiscing transversely;

FIG. 339.—*Gossypium herbaceum*—Branch. (*Sayre.*)

pollen grains echinate; pistil loosely or strongly syncarpous, rarely sub-apocarpous of thirty to five carpels. Fruit either a circular set of cocci (*Malva*), follicles, or a capsule (*Gossypium*). Seeds albuminous with oily and mucilaginous albumen.

Official drug	Part used	Botanical origin	Habitat
Althæa	Root (peeled)	Althæa officinalis	Europe and Asia
Althæa Folia	Leaves	Althæa officinalis	Europe and Asia
Gossypii Cortex	Bark of root (recently gathered)	Cultivated varieties of: Gossypium herbaceum	Arabia, United States, East Indies
		Gossypium Barbadense	West Indies
		Gossypium hirsutum	Egypt, Arabia and India
Gossypium Purificatum	Hairs of seed	Cultivated varieties of Gossypium herbaceum	Arabia, East Indies, United States
Oleum Gossypii	Fixed oil from Seminis	Cultivated varieties of G. herbaceum and other Gossypium species	United States, Asia, Africa and W. Indies
Malvæ Folia	Leaves	Malva sylvestris	Europe
		Malva rotundifolia	

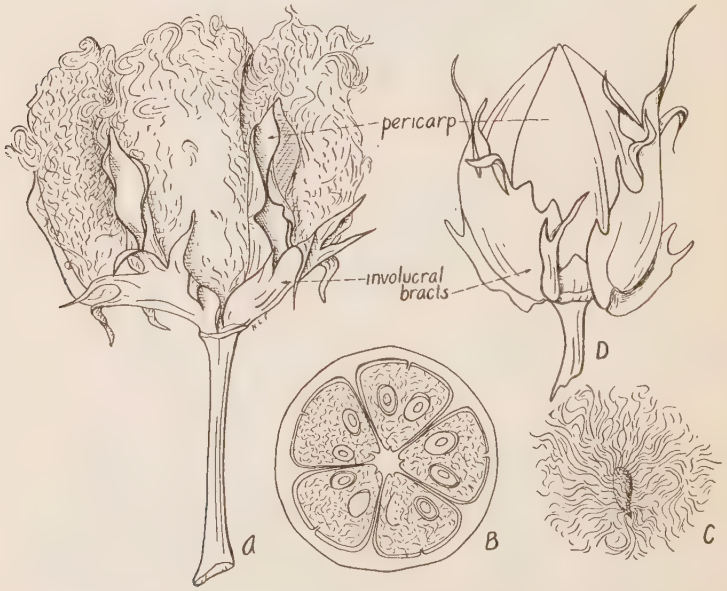

FIG. 340.—Upland cotton (*Gossypium hirsutum*). *A*, mature boll opened out; *B*, cross-section of young boll; *C*, single seed with hairs; *D*, young boll. (*Robbins.*)

Unofficial	Part used	Botanical origin	Habitat
Althæa Flores (larger mallow flowers)	Flowers (dark colored)	Althæa rosea	Europe
Malvæ Flores (mallow flowers)	Flowers	Malva sylvestris Malva rotundifolia	Europe

ORDER PARIETALES

This order includes a large variety of plants most of which have parietal placentation, separate sepals and numerous stamens. Belonging to this order are the Violets, Begonias, St. John's Worts, Damiana, Passion Flowers, Rock Roses, Tea and Camellias, Canella, etc.

Theaceæ or Tea Family (*Ternstræmiaceæ, Cammeliaceæ*).—Evergreen shrubs or low branching, or tall, often heavy trees with watery juice. Leaves for the most part alternate, evergreen, often leathery, sometimes membranous; stipules either bud scales and caducous, or often absent; leaf margins sinuate or serrate (*Thea*). Inflorescence a raceme becoming by condensation terminal, one-flowered. Flowers regular, perfect, pentamerous; sepals five, rarely four to three, deciduous, occasionally subtended by bracteolar scales; petals five, brittle and succulent, varying from greenish-white or greenish-yellow through yellow to white or, whitish pink to pink, scarlet, crimson, very rarely a tendency toward purple; stamens typically five but, as they grow, they subdivide into staminal leaflets, so that in their mature condition they are apparently indefinite and mono- to polyadelphous; stamens inserted hypogynously or perigynously and opposite the petals; pistil of typically five syncarpous carpels but reduced in some species to four to three or two. Fruit usually a capsule (*Thea*), five- to three-celled, dehiscing longitudinally, more rarely a fleshy, semi-baccate, semi-drupaceous, indehiscent fruit. Seeds with scanty or no albumen and often attached to the inner angle of cells by projecting spongy placentæ.

Official drug	Part used	Botanical origin	Habitat
Caffeina	Feebly basic substance	Thea sinensis	Eastern Asia
Unofficial			
Thea (Tea)	Leaves	Thea sinensis var. Bohea and viridis	Eastern Asia

Guttiferæ or Gamboge Family.—Tropical trees (*Garcinia*), rarely shrubs, containing resinous principles in schizogenous resin canals found in cortex and pith. Leaves opposite, coriaceous. Flowers

FIG. 341.—*Garcinia Hanburyi*—Branch. (*Sayre.*)

dicœcious, generally pentamerous or tetramerous with usually five stamens which are subdivided. Fruit a berry (*Garcinia Hanburyi*), drupe or capsule. Seeds generally large; embryo large to huge, often with enlarged radicle and reduced or absorbed cotyledons.

Official drug	Part used	Botanical origin	Habitat
Cambogia	Gum resin	Garcinia Hanburyi	Siam, Cochin China and Annam

Hypericaceæ or St. John's Wort Family.—Herbs or shrubs of temperate climes with opposite (*Hypericum perforatum*), rarely whorled branches and balsamic, resinous juices, which, in the herbaceous species, are secreted by black or pellucid glands found in the leaf parenchyma. Leaves entire, opposite, usually sessile, exstipulate, and dotted. Flowers, regular, hypogynous and arranged in panicles or forked cymes. Petals usually 5. Stamens usually indefinite, rarely definite, often in 3–5 sets, more rarely monadelphous or free. Pistil of usually 3 5 carpels with 3 5 celled compound ovary and as many filiform styles as carpels. Fruit a capsule with usually septicidal dehiscence (*Hypericum*) or a berry. Seeds small, numerous, anatropous and exalbuminous.

Unofficial drug	Part used	Botanical origin	Habitat
Hypericum	Entire plant	Hypericum perforatum	Europe

Canellaceæ Family.—Trees the bark of which contains aromatic principles. Leaves alternate, pellucid-punctate. Flowers regular, golden-yellow, and arranged in terminal or axillary cymes. Fruit a berry containing two to many seeds with oily and fleshy albumen.

Official drug	Part used	Botanical origin	Habitat
Canella	Inner bark	Canella Winterana	Florida and West Indies

Bixaceæ Family.—Tropical shrubs or trees. Leaves alternate, simple with minute or no stipules. Flowers hermaphrodite or unisexual, regular, stamens hypogynous, mostly indefinite with anthers opening by slits, rarely by one or two apical pores (*Bixa*). Fruit fleshy or dry. Seeds with fleshy albumen and sometimes covered with a fleshy arilus (*Bixa Orellana*).

Unofficial drug	Part used	Botanical origin	Habitat
Annatto	Coloring matter	Bixa Orellana	Tropical America and Madagascar

Flacourtiaceæ or Flacourtia Family.—A family of chiefly tropical trees and shrubs with simple, alternate leaves, staminate, pistillate

and hermaphrodite flowers, frequently diœcious or polygamous, with a one-celled ovary. The fruits are either berries (*Taraktogenos Kurzii* or Leprosy plant), drupes or rarely capsules. The seeds are albuminous.

Official drug	Part used	Botanical origin	Habitat
Oleum Chaulmoogræ	Fixed oil from seeds	Taraktogenos Kurzii	Burma

Violaceæ or Violet Family.—Herbs or shrubs. Stems upright, rarely creeping, spreading or acaulescent. Leaves either cauline or radical, stipulate, alternate, simple to pinnatifid or palmate.

Flowers pentamerous, regular or irregular (*Viola*) and sometimes cleistogamous; sepals 5; petals 5, unequal, the lowermost often spurred at the base; stamens 5, hypogynous, with adnate, introrse anthers and usually closely arranged or coherent around the ovary, in *Violets* the two lower stamens bearing spurs which extend into the spur of the corolla; ovary, sessile, one-celled with 3 to 5 parietal placentas; style usually club-shaped. Fruit a loculicidally dehiscent capsule (*Viola*), rarely baccate. Seeds albuminous.

Unofficial drug	Part used	Botanical origin	Habitat
Pansy	Entire herb	Viola tricolor	Temperate regions
Viola odorata	Fresh flowers and root	Viola odorata	Europe

Turnaceæ or Damiana Family.—Tropical herbs, shrubs or trees. Leaves alternate, simple, petioled, exstipulate. Flowers perfect, regular, axillary, pentamerous with one-celled ovary. Fruit a capsule with three valves. Seeds strophiolate with albuminous embryo.

Official drug	Part used	Botanical origin	Habitat
Damiana	Leaves	Turnera diffusa	California, Lower
		Turnera aphrodisiaca	California, Mexico, S. America, West Indies

Passifloraceæ or Passion Flower Family.—Herbaceous or woody vines climbing by tendrils. Leaves alternate, simple, entire, lobed or compound. Flowers perfect or imperfect, solitary; peduncles jointed at the flower; perianth petaloid with urceolate or tubular tube and four to five or eight to ten partite and two-seriate limb, the

throat usually crowned by one or more series of subulate filaments which are frequently colored; gynophore elongating, supporting the stamens and pistil. Fruit a one-celled berry (*Passiflora*) or a three- to five-valved, dehiscent capsule containing numerous seeds.

Official drug	Part used	Botanical origin	Habitat
Passiflora	Flowering and fruiting top	Passiflora incarnata	United States

Caricaceæ or Papaw Family.—A family of latex-containing trees composed of two genera indigenous to tropical America. Of chief pharmaceutic interest is the species *Carica Papaya*, the Papaw or Melon tree, the fruit of which yields Papain, a valuable digestive ferment. This plant is a tree about 20 feet high which bears at its summit a cluster of deeply lobed, petiolate leaves and diœcious flowers. The fruit is a berry, the size of one's head and contains an acrid milky juice from which papain can be precipitated by the addition of alcohol.

Cistaceæ or Rock Rose Family.—Herbs or shrubs whose stem and branches are often glandular, pubescent or tomentose, with simple or stellate trichomes. Leaves simple, entire, the lower ones opposite, upper alternate. Flowers perfect, regular, terminal, and solitary or in cymes or unilateral racemes; sepals five, the two external ones often bractiform or wanting; petals five, as in *Helianthemum* or Rock Rose and *Hudsonia*, rarely three or none, as in *Lechea* or Pinweeds; stamens hypogynous, indefinite; carpels three to five, ovary free, one-celled. Fruit a one-celled, three- to five-valved capsule.

Unofficial drug	Part used	Botanical origin	Habitat
Helianthemum	Herb	Helianthemum canadense	Eastern United States

XX. **Order Opuntiales.**—*Cactaceæ or Cactus Family.*—Herbaceous, rarely arborescent (*Cereus giganteus* or Giant Cactus), more or less succulent plants living in warm, dry (*Pereskia*), usually desert situations, rarely becoming epiphytic and correspondingly modified. Stems, accordingly, varying from elongate, slightly enlarged, green (*Pereskia*), to flattened and ribbed (*Selenicereus*), to flattened and shortened as in the Prickly Pear (*Opuntia*), to condensed (*Echinocactus*, *Echinocereus*, etc.), to greatly condensed (*Mamillaria*).

Leaves alternate, stipulate or exstipulate, enlarged and more or less fleshy (*Pereskia*), becoming reduced, green and semicircular (*Opuntia*), or modified into spines, or wholly absorbed. Flowers regular, solitary, or fascicled in axils of leaves; sepals five; petals similar to

FIG. 342.—*Daphne mezereum* (*Fam. Thymeleaceæ*) —Fruiting branch and flowers. (*Sayre.*)

sepals, petaloid, small to much enlarged, in color varying from yellow to white or from yellow to yellowish-pink, pink, scarlet or crimson; stamens indefinite, inserted at varying levels in the throat of a greatly expanded upgrown receptacle; pistil generally tricarpellary;

ovary inferior, often deeply sunk in upgrown receptacular part; style thread-like, divided above into as many stigmas as carpels. Fruit a receptacular berry enclosing numerous small seeds. Seeds exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Cactus Grandiflorus	Fresh succulent stem	Selenicereus grandiflorus	Jamaica

ORDER MYRTALES OR MYRTIFLORÆ

This order includes trees, shrubs and herbs, most of which possess tetramerous flowers with an inferior ovary. It contains in addition to the families here considered the *Rhizophoraceæ* or Mangrove Family, the *Onagraceæ* or Evening-Primrose Family which is represented by the Oenotheras or Evening Primroses, the Willow Herbs (*Epilobium*) and the cultivated Fuchsia, the *Elæagnaceæ*, represented by the Buffalo-Berry, the *Trapaceæ*, containing the Water-Chestnut or *Trapa natans* and the *Lecythidaceæ* or Monkey-Pot Family which contains the Brazil-Nut whose seeds are edible.

Thymelæaceæ or Mezereum Family.—Shrubs (*Daphne Mezereum*) or low trees, usually of branching habit, the stems developing long tenacious bast fibers. Leaves alternate, rarely opposite, exstipulate, coriaceous, simple, varying from lanceolate to ovate. Inflorescence a condensed raceme or spike. Flowers perfect, polygamous or dicœcious, small, with calyx alone of the perianth parts developed. This is crimson-purple in *Daphne Mezereum*. Sepals usually fused to form a tube or cup-shaped perianth. Stamens usually eight in two rows of four longer and four shorter (*Daphne Mezereum*) inserted on the calyx tube. Pistil monocarpellary; ovary superior, mostly one-celled with a single pendulous ovule. Fruit a nut, drupe or berry (*Daphne*).

Official drug	Part used	Botanical origin	Habitat
Mezereum	Bark	Daphne Mezereum Daphne Gnidium Daphne Laureola	Europe and Asia

Granataceæ (*Punicaceæ*) or *Pomegranate Family.* Herbs (*Cuphea*), shrubs (*Decodon*) or low trees (*Punica*). Leaves either alternate, opposite (*Punica*) or whorled, simple, usually lanceolate to

ovate, entire, often glandular and viscous. Inflorescence a raceme, spike, or condensed cyme. Flowers perfect, usually regular, but pass more or less to irregular, sometimes very irregular, as in genus *Cuphea;* sepals five to four, more or less fused below in themselves and with calyx tube; petals commonly five, often frilled or crumpled, inserted on the mouth of the calyx tube; stamens fifteen, ten or five, in alternate rows of five each, inserted hypogynously or perigynously;

FIG. 343.—*Punica granatum*—Branch with flowers. (*Sayre.*)

pistil six,- five-, four-, two-, rarely one-carpeled with as many cavities in the ovary and numerous small ovules; style elongate with pointed or knobbed stigma. Flowers of *Punica granatum* are scarlet in color. Fruit a baccate capsule (*Punica granatum*) or capsule, dehiscing longitudinally or transversely. Seeds exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Granatum	Bark	Punica Granatum	India
Unofficial			
Granati Fructus Cortex	Rind of fruit	Punica Granatum	India
Henna	Leaves	Lawsonia inermis	Egypt, Arabia

FIG. 344.—*Eucalyptus globulus*—Branch. (*Sayre.*)

Myrtaceæ or Myrtle Family.—Rarely herbs (*Careya*) mostly shrubs or trees, some being the tallest trees known (*Eucalyptus*). Stems often tend to develop cork in flakes which separate much as

FIG. 345.—*Caryophyllus aromaticus.* (*Sayre.*)

in the Buttonwoods. Leaves rarely alternate, nearly always opposite, entire, often glistening, subcoriaceous to coriaceous (*Eucalyptus, Pimenta,* etc.), frequently edge-on in position upon branches. Inflorescence cymose, at times forming scorpioid cymes, becoming

condensed into small fascicles, or each cyme condensing into a solitary flower.

Flowers regular or very rarely irregular from the lop-sided development of the stamens. Symmetry rarely hexamerous, typically pentamerous, not infrequently reduced to tetramerous (*Clove*); sepals five, six or four, aposepalous, or synsepalous at base, superior, and inserted around the edge of an expanded, upgrown, receptacular disc, varying from green and more or less expanded to short, thick fleshy (*Clove*) or reduced to teeth (*Eucalyptus*); petals equal in number to the sepals, more or less petaloid and enlarged, rarely reduced and wanting, varying in color from green through greenish-yellow to white (*Caryophyllus*) or from whitish to pink, scarlet, crimson, purple and blue, petals sometimes synpetalous and cup-like, detaching as the flower opens; stamens usually indefinite and epigynous, varying in the color of their filaments as do the petals; pistil rarely of ten to six carpels usually of five, not infrequently, as in Clove, of four carpels; ovary inferior or semi-inferior, as many-celled as there are carpels and with central placentation; style elongate; stigma undivided. Fruit either a hard, woody indehiscent nut (Brazil Nut), a capsule dehiscing at apex (*Eucalyptus*) or berry (*Carophyllus*). Seeds exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Eucalyptus	Scythe-shaped leaf	Eucalyptus globulus	Australia and Tasmania
Oleum Eucalypti	Volatile oil	Eucalyptus globulus and some other Eucayptus sp.	
Eucalyptol	Organic oxide	Eucalyptus globulus	
Caryophyllus	Flower buds	Caryophyllus aromaticus	Molucca Islands
Oleum Caryophylli	Volatile oil	Caryophyllus aromaticus	
Eugenol	Aromatic phenol	Caryophyllus aromaticus	
Pimenta	Fruit	Pimenta officinalis	West Indies Central America Mexico
Oleum Pimentæ	Vol. oil	Pimenta officinalis	
Oleum Cajuputi	Volatile oil from leaves and twigs	Var. of Melaleuca Leucadendron	East Indies

Official drug	Part used	Botanical origin	Habitat
Eucalypti Gummi	Dried gummy exudate	Eucalyptus rostrata and other sp. of Eucalyptus	Australia
Oleum Myrciæ	Volatile oil	Pimenta acris	West Indies
Unofficial			
Bay Leaves	Leaves	Pimenta acris	West Indies

Combretaceæ or Myrobalans Family.—Mostly tropical shrubs and trees containing considerable tannin. Leaves exstipulate, alternate or opposite, simple, pinnately veined, entire or toothed. Inflorescence a raceme, spike or head. Flowers regular, perfect or imperfect. Fruit a drupe, frequently longitudinally winged, containing a single seed.

Unofficial drug	Part used	Botanical origin	Habitat
Combretum	Leaves	Combretum sundaicum	Sumatra

ORDER UMBELLALES OR UMBELLIFERÆ

This order includes the Ginseng Family (*Araliaceæ*) represented by Ginseng, Spikenard, and Virginian Sarsaparilla, the *Umbelliferæ* or Parsley Family which contains Fennel, Anise, Coriander, Caraway, Poison Hemlock, Water Hemlock and other medicinal plants, and the Dogwood Family (*Cornaceæ*) which includes the Dogwoods and Sour Gum. All of these families agree in usually possessing inflorescences consisting of umbels and flowers with an inferior ovary and a single whorl of stamens.

Araliaceæ or Ginseng Family.—Herbs, as Ginseng (*Panax quinquefolium*, English Ivy (*Hedera Helix*), Wild or Virginian Sarsaparilla (*Aralia nudicaulis*), etc., undershrubs (*Aralia hispida*, etc.), shrubs, as Bristly Sarsaparilla (*Fatsia horrida*), or trees, as Hercules Club (*Aralia spinosa*), with stems which are more or less hollow along internodes and solid at nodes. Leaves alternate, varying from simple to trifoliate or to multipinnate (tropical Aralias) or passing by telescoping into compound-palmate. Leaves serrate-margined and along with stem they develop volatile oil, resin and gum contents in secretion reservoirs. Inflorescence varying from a raceme of umbels to a raceme and even to condensed racemose umbels. Flowers regular, generally pentamerous, small, generally inconspicu-

ous, green, greenish-yellow to rarely white, usually hermaphrodite but sometimes polygamous or diœcious; sepals five, rarely four; petals five, rarely four, often greenish to greenish-yellow, occasionally white, seldom pink in color; stamens varying from indefinite to ten to commonly five, opposite sepals, and, like sepals, epigynous in insertion; anthers versatile; pistil occasionally fifteen- to ten-, usually five-carpellate; ovary as many celled with one or rarely two pendulous ovules in each cavity; styles distinct ending in knob-shaped stigmas. Fruit a berry. Seeds albuminous, with a single seed coat.

Official drug	Part used	Botanical origin	Habitat
Aralia	Rhizome and roots	Aralia racemosa	Eastern United States and Canada
Unofficial			
Aralia Nudicaulis	Rhizome	Aralia nudicaulis	Eastern United States and Canada
Aralia Spinosa	Bark	Aralia spinosa	Eastern United States
Ginseng	Root	Panax quinquefolium	North America
Panax Repens	Rhizome	Panax repens	Japan

Umbelliferæ or Parsley Family.—Herbs, rarely shrubs, often of rapid growth, and with upright, fistular (hollow at internodes, solid at nodes), often grooved and ridged stems. Leaves alternate, compound and usually much divided, exstipulate, but with expanded sheathing and flattened leaf base (*pericladium*), that ensheathes the stem. Inflorescence a simple or often compound umbel surrounded by an involucre of bracts or of bracteoles. Flowers small, pentamerous, with inferior ovary and superior floral parts. Sepals minute, tooth-like, inserted above inferior ovary, or absorbed. Petals small, usually yellow to white, rarely pink to purple, distinct, each with inflexed tip. Stamens five, epigynous, inserted below a nectariferous, epigynous disc, incurved in bud. Carpels two, fused into bicarpellate pistil. Ovary two-celled, with one pendulous ovule in each cell, ovarian wall traversed by oleoresin canals; styles two, distinct above the nectar disc or stylopod. Fruit a dry, splitting fruit or cremocarp, that splits lengthwise into two mericarps

FIG. 346.—*Conium maculatum* L., the poison hemlock. Note spotted stems decompound leaves and compound umbels of white flowers. The poisonou juice of this plant was employed as a potion by the ancient Greeks which wa given to criminals as a means of capital punishment.

which hang for a time by a forked carpophore. Seeds single in each mericarp, albuminous, each with a single seed coat.

Official drug	Part used	Botanical origin	Habitat
Anisum	Ripe fruit	Pimpinella Anisum	Asia Minor, Egypt and Greece
Oleum Anisi	Volatile oil	Pimpinella Anisum	
Anethol	Methyl ether of para-propenyl phenol	Pimpinella Anisum, Fœniculum vulgare	
Fœniculum	Ripe Fruit	Fœniculum vulgare	Mediterranean region
Oleum Fœniculi	Volatile oil	Fœniculum vulgare	
Sumbul	Rhizome and roots	Ferula Sumbul or other closely related sp. of Ferula having a musk-like odor	Asia
Carum	Fruit	Carum Carvi	Europe, Asia
Oleum Cari	Vol. oil	Carum Carvi	
Conium	Unripe fruit	Conium maculatum	Europe
Asafœtida	Gum resin	Ferula fœtida, F. Asafœtida, etc.	Persia and Afghanistan
Coriandrum	Ripe fruit	Coriandrum sativum	Mediterranean and Causcasian regions
Oleum Coriandri	Volatile oil	Coriandrum sativum	
Angelicæ Fructus	Ripe Fruit	Angelica Archangelica and other species of Angelica	Northern Europe and Siberia
Angelicæ Radix	Rhizome and roots	Angelica Archangelica and other species of Angelica	Northern Europe and Siberia
Apii Fructus	Ripe fruit	Apium graveolens	Southern Europe
Unofficial			
Imperatoria	Root	Imperatoria Ostruthium	Europe
Ammoniacum	Gum-resin	Dorema Ammoniacum	Persia
Galbanum	Gum-resin	Ferula galbaniflua	Persia and Afghanistan
Levisticum	Root	Levisticum officinale	Europe
Pimpinella	Roots	Pimpinella Saxifraga, Pimpinella magna	Central Europe
Petroselinum	Ripe fruit	Petroselinum sativum	Southern Europe and Asia Minor
Petroselini Radix	Root	Petroselinum sativum	

Cornaceæ or Dogwood Family.—Herbs, as Bunchberry (*Cornus canadensis*), etc., shrubs, as Blood-Twig Dogwood (*Cornus sanguinea*), etc. or trees, as Flowering Dogwood (*Cornus florida*) and Sour Gum (*Nyssa sylvatica*), etc. Leaves simple, alternate (Sour Gum), or opposite (Dogwoods). Inflorescence an umbel or determinate head (*glomerule*), the whole being surrounded by an enlarged and more or less petaloid involucre. Flowers regular, rarely pentamerous, more frequently tetramerous; sepals usually four, small, tooth-like or absorbed; petals usually four, small, greenish to yellowish to white (*Cornus florida*), rarely pink or crimson; stamens four or five, alternate to the petals and inserted with the sepals and petals epigynously around and between the nectar disc; pistil syncarpous, bicarpellate, rarely tricarpellate; ovary as many celled with one pendulous ovule in each cavity; style usually simple, ending in rounded or slightly bilobed stigma. Fruit a two-seeded drupe. Seeds albuminous with single seed coat.

Official drug	Part used	Botanical origin	Habitat
Cornus	Bark of root	Cornus florida	Eastern United States and Canada

SUB-CLASS—SYMPETALÆ (GAMOPETALÆ OR METACHLAMYDEÆ)

A division of dicotyledonous plants in which the flowers possess both calyx and corolla, the latter with petals more or less united into one piece.

ORDER ERICALES

Ericaceæ or Heath Family.—Sub-herbaceous, as Pipsissewa (*Chimaphila*), suffruticose, as the Heather (*Calluna*), fruticose (Azaleas, Mountain Laurel, etc.), rarely sub-arborescent (*Arbutus unedo* or Strawberry Tree) plants. Roots fibrous often saprophytically associated, rarely tuberous or more or less enlarged. Stem upright, ascending or creeping, more or less woody, rarely through saprophytic connection becoming soft, annual and white above ground, as in Indian Pipe (*Monotropa uniflora*). Leaves alternate, simple, entire, exstipulate, rarely soft, delicate, herbaceous (*Azaleas*), usually leathery to wiry and evergreen, more rarely (*Ptero-*

spora, Monotropa, etc.) becoming greenish-blue, bluish-yellow, yellowish-white to white and correspondingly saprophytic. Inflorescence typically a raceme (*Pyrola, Andromeda, Gaylussacia, Erica, Arctostaphylos Uva Ursi,* etc.) but raceme condensed into a racemose umbel (*Azalea,* etc.) or further reduced to a few flowers or, in the degraded saprophytic condition to one flower (*Monotropa uniflora*).

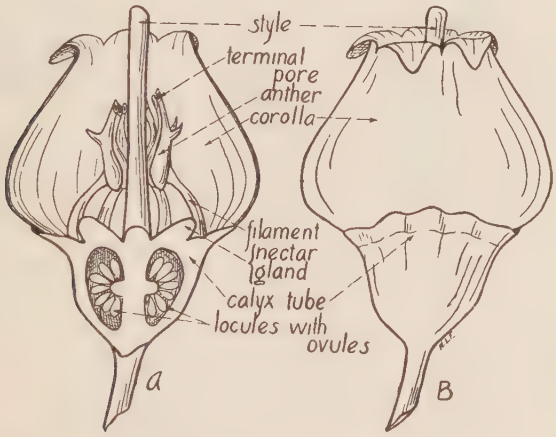

Fig. 347.—Flower of a Blueberry (*Vaccinium*). *A*, median lengthwise section; *B*, external view. (*Robbins.*)

Flowers regular, passing to irregular (*Rhododendron*), pentamerous or tetramerous; sepals five to four, rarely fewer, apo- to synsepalous, usually green, sometimes brightly petaloid; petals five, more rarely four, slightly to deeply synpetalous, cup-shaped, as in Mountain Laurel (*Kalmia*) to urceolate (*Arctostaphylos, Andromeda,* etc.), yellow to white or through yellow-pink to scarlet to crimson to crimson-purple; stamens ten to eight in two circles of five to four each, becoming by absorption of inner circle, five to four only, hypogynous, epipetalous or epigynous; anthers two-celled, dehiscing by apical pores, as in Bearberry (*Arctostaphylos*) or apical slits; pollen sometimes agglutinated into long viscous threads; pistil five- to four-, rarely six- to eight-carpeled, superior, rarely semi-inferior to inferior, as in Blueberries (*Vaccineæ*); ovary as many celled as there are carpels; style elongated, filiform, usually five-

to four-lobed. Fruit a capsule, as in *Epigæa repens* or *Trailing Arbutus*, berry, as in Blueberries (*Vaccinium*) and Huckleberries (*Gaylussacia*) or false drupe, as in the Wintergreen (*Gaultheria procumbens*). Seeds small, anatropous.

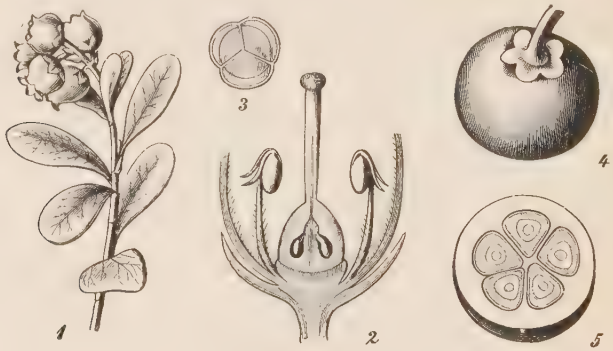

FIG. 348.—*Arctostaphylos Uva ursi.* 1. Twig bearing spatulate leaves and urn-shaped flowers. 2. Flower in longitudinal section. 3. Pollen tetrad. 4. Fruit. 5. Cross section of fruit. × 2 –5. (*From Strasburger, Noll, Schenck and Schimper after Berg and Schmidt.*)

Official drug	Part used	Botanical origin	Habitat
Chimaphila	Leaves	Chimaphila umbellata	United States, Canada, Northern Europe and Asia
Uva Ursi	Leaves	Arctostaphylos Uva Ursi	Northern United States and Canada, Europe and Asia
Methylis Salicylas	Volatile oil	Gaultheria procumbens	United States and Canada
Unofficial			
Gaultheria	Leaves	Gaultheria procumbens	United States and Canada

ORDER EBENALES

Sapotaceæ or Star Apple Family.—Tropical shrubs or trees (*Palaquium*) characterized by the presence of laticiferous sacs in the pith and cortex of the stems and adjoining the veins of the leaves. Leaves alternate, exstipulate, evergreen and coriaceous. Flowers perfect,

large and axillary. Fruit a berry (*Palaquium*) rarely a capsule (*Ponteria*).

Unofficial drug	Part used	Botanical origin	Habitat
Gutta Percha	Purified coagulated milky exudate	Various species of Palaquium and Payena	Malay Archipelago
Chicle	Dried latex	Achras Sapota	Mexico and Central America

Styraceæ or Benzoin Family.—Shrubs or low trees. Leaves alternate to opposite, entire, often acuminate. Flowers hermaphrodite, regular, rarely sub-irregular, either in condensed fascicles or solitary in the axils of the leaves; sepals and petals typically five each; corolla often white, rarely pinkish or yellowish; stamens many to four to two, perigynous or sub-hypogynous; pistil bicarpellary or four to five carpellate. Fruit either fleshy or dry, often winged and rarely as many-celled as there are carpels.

Official drug	Part used	Botanical origin	Habitat
Benzoinum	Balsamic resin	Styrax Benzoin and some other species of Styrax	East Indies and Siam

ORDER GENTIANALES

Oleaceæ or Olive Family.—Shrubs, as Lilacs (*Syringa*), Golden Bell (*Forsythia*) or trees (as the Ash (*Fraxinus*), Olive (*Olea*), etc. with stems possessing close white wood, and slightly swollen or enlarged nodes. Leaves opposite, decussate, simple, rarely pinnately-compound (Ash). Inflorescence dichesial or scorpioid cymes but tending constantly toward condensation and so in the Lilac, the inflorescence becomes a clustered raceme of cymes (thyrsus). Flowers regular, pentamerous or tetramerous; sepals small, green, rarely petaloid, synsepalous; petals synpetalous, elongated into a narrow tube, expanding above into a stellate limb; stamens very rarely five, rarely four to three, nearly always two, epipetalous and high set on corolla tube; pistil bicarpellate, rarely of three to four carpels; ovary two-celled with two to one pendulous ovules in each cavity. Fruit either a capsule (Lilac), drupe (Olive), berry (Privet)

or a winged indehiscent akene (Ash). Seeds with moderate to scanty albumen, becoming occasionally exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Manna	Dried saccharine exudate	Fraxinus Ornus	Southern Europe
Oleum Olivæ	Fixed oil	Olea Europæa	Southern Europe, Algeria, Asia
Chionanthus	Bark of root	Chionanthus virginica	Southern United States
Unofficial drug			
Fraxinus	Bark	Fraxinus Americana	Northern United States and Canada

Loganiaceæ or Logania Family.—Herbs (*Spigelia*, etc.), woody vines (*Gelsemium*, etc.) or trees (*Strychnos Nux Vomica*, etc.) with a bitter juice usually containing alkaloids. Stem, rarely herbaceous, usually woody, often long climbing and rope-like (*Gelsemium*), usually with a bicollateral bundle system. Leaves opposite, stipulate or exstipulate. Inflorescence racemose or cymose (*Spigelia*) (scorpioid cyme in *Strychnos*), sometimes condensed into solitary, axillary flowers. Flowers perfect, usually regular; calyx gamosepalous; corolla gamopetalous, hypogynous, rotate, campanulate or infundibuliform; stamens inserted on the corolla tube or throat and with thread-like filaments; ovary superior, two-celled; style elongate with bifid stigma; ovules numerous. Fruit usually a capsule, septicidally dehiscent (*Gelsemium sempervirens*), or loculicidally dehiscent (*Spigelia marilandica*), sometimes a berry (*Strychnos Nux Vomica*) or drupe. Seeds numerous or solitary, sometimes winged.

Official drug	Part used	Botanical origin	Habitat
Nux Vomica	Seeds	Strychnos Nux-Vomica	India
Strychnina	Alkaloid from seed	Strychnos Nux-Vomica and other Loganiaceæ	Eastern Hemisphere
Gelsemium	Rhizome and roots	Gelsemium sempervirens	Southern United States
Ignatia	Seeds	Strychnos Ignatii	Philippine Islands

FIG. 349.—*Strychnos Nux vomica*—Flowering branch and seeds. (*Sayre.*)

Unofficial drug	Part used	Botanical origin	Habitat
Spigelia	Rhizome and roots	Spigelia marilandica	Southern United States

FIG. 350.—*Gentiana lutea*—Flowering head and dissected flower. (*Sayre.*)

Gentianaceæ or Gentian Family.—Herbs, often low-growing. Roots and short stems sometimes more or less thickened (*Gentiana lutea*). Leaves opposite, decussate, entire, exstipulate. Inflorescence cymose (*Gentiana lutea*) or condensing to a single, solitary,

terminal flower (*Gentiana verna*, *G. acaulis*, etc.). Flowers regular, perfect, pentamerous or tetramerous, sepals five to four, green, more or less synsepalous, not infrequently everted or reflexed, corolla of five, rarely four petals, more or less synpetalous, in shape passing from open-stellate, as in *Gentiana lutea*, through many stages of connation to long-tubed, as in *Gentiana acaulis;* stamens five, epipetalous; pistil bicarpellate; ovary one-celled or incompletely two-celled; style more or less elongated with bilobed to divided stigma. Fruit a capsule. Seeds albuminous.

Official drug	Part used	Botanical origin	Habitat
Gentiana	Rhizome and root	Gentiana lutea	Europe
Chirata	Entire plant	Swertia Chirayita	Northern India
Centaurium	Flowering plant	Erythræa Centaurium	Europe
Unofficial			
Sabbatia	Herb	Sabbatia angularis	Eastern United States and Canada
Menyanthes	Leaves	Menyanthes trifoliata	Europe and Asia

Apocynaceæ or Dog Bane Family.—Herbs, rarely shrubs, not infrequently clambering or climbing in habit (*Allamanda*). Stem and branches show bicollateral bundles. Stem, leaves and flowers have latex tubes which ramify through the cortex and mesophyll tissues. Leaves alternate, opposite or verticillate, simple, entire, deciduous or evergreen. Inflorescence cymose. Flowers regular, pentamerous, rarely tetramerous; sepals five, gamosepalous, green, rarely subpetaloid to petaloid; petals five, slightly to deeply gamopetalous, in shape varying from open tubular, stellate, to elongate tubular to elongate funnel-shaped, in color varying from greenish-yellow to white or from yellow-red to crimson to crimson-purple to nearly purple-blue; stamens five, epipetalous; pistil usually bicarpellate; ovary two-celled with central placentation; style more or less elongate with terminal brush of hairs, knobbed or multifid; stigma circular band or circular spur beneath terminal style swelling. Fruit

two follicles (*Apocynum*, etc.), a berry, drupe, or capsule. Seeds flattened, frequently hairy, albuminous.

Official drug	Part used	Botanical origin	Habitat
Strophanthus	Seed (deprived of awn)	Strophanthus Kombe Strophanthus hispidus	Africa

FIG. 351.—*Strophanthus hispidus*—Branch and seed with comose awn. (*Sayre.*)

Strophanthin	Glucoside	Strophanthus Kombe	Africa
Apocynum	Rhizome and roots	Apocynum cannabinum	United States and Canada

Unofficial drug	Part used	Botanical origin	Habitat
Aspidosperma	Bark	Aspidosperma Quebracho blanco	Argentine Republic

Asclepiadaceæ or Milkweed Family.—Herbs or shrubs containing a milky juice, many species yielding rubber. Leaves entire, more or less fleshy, sometimes verticillate. Inflorescence usually a dichesial or scorpioid cyme. Flowers regular, pentamerous; sepals woolly, small, synsepalous; petals five, rarely four, synpetalous, elongated into awls; the corolla varying in shape from stellate to campanulate and in color from pale green to yellow, to greenish-brown, chocolate, or from white to yellow, to scarlet, to crimson, to purple, to blue; stamens five, epipetalous, fused in relation forming a cylindrical swollen mass around the central pistil; filaments flattened and furnished with a crown having various appendages; anthers two-celled, each cell containing a pollen mass (pollinium), adhering to the glandular prominences of the stigma; pistil bicarpellate, superior. Fruit typically two dry follicles (*Asclepias*), rarely becoming succulent or bladdery. Seeds numerous, compressed, imbricate, with a comose appendage.

Official drug	Part used	Botanical origin	Habitat
Asclepias	Root	Asclepias tuberosa	United States
Condurango	Bark	Marsdenia Condurango	Peru and Ecuador

ORDER TUBIFLORÆ OR POLEMONIALES

Convolvulaceæ or Morning Glory Family.—Frequently herbaceous, more rarely sub-woody or woody, perennial climbing plants with underground parts sometimes swollen into tuberous roots (Jalap, Sweet Potato, Wild Man of the Earth). Stems rarely short, upright or tufted, usually elongate and circumnutating in action. Vascular bundles frequently bicollateral. Leaves alternate, simple, exstipulate, varying from cordate to cordate-sagittal, to broad-reniform to reniform, palmately lobed to palmatifid to palmately-compound (*Ipomœa* shows all these transitions). Stem and leaves frequently contain a dull, viscous, watery to milky-white juice. Inflorescence a

scorpioid cyme, becoming reduced in some forms to a solitary flower. Flowers pentamerous; sepals five, green, gamosepalous; corolla varying in shape from rotate to funnel-like with expanded mouth, in color from greenish-yellow to white or through yellowish-pink to

FIG. 352.—*Convolvulus scammonia*—Branch. (*Sayre.*)

scarlet, crimson, purple or blue; stamens five, often with the bases of the filaments expanded; pistil bicarpellate; ovary two celled, superior, often surrounded by a nectar girdle; style filiform with bilobed or bifid stigma. Fruit usually a capsule (*Exogonium, Convolvulus*, etc.), dehiscing septifragally, rarely a berry. Seeds scantily albuminous to exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Jalapa	Tuberous root	Exogonium Jalapa	Mexico
Ipomœa	Root	Ipomœa orizabensis	Mexico
Unofficial			
Tampico Jalap	Root	Ipomœa simulans	Mexico
Wild Jalap	Root	Ipomœa pandurata	United States
Turpeth Root	Root	Operculina Turpethum	East Indies
Scammoniæ Radix	Root	Convolvulus Scammonia	Asia Minor, Greece, Syria

Hydrophyllaceæ or Water Leaf Family.—Annual, herbaceous, rarely perennial woody plants whose stems, branches, leaves and sepals are often viscous and glandular hairy. Leaves alternate, exstipulate, from simple linear to pinnatipartite to pinnate. Inflorescence rarely expanded, usually scorpioid cymes. Flowers small to large, funnel-form in Yerba Santa (*Eriodictyon californicum*); sepals five, green; petals five, regular; corolla varying from small stellate with slightly fused petals to large rotate, campanulate or tubular, in color varying from greenish-white or yellow to rarely white, often pink, purple or blue; stamens five, rarely with alternate staminodes; pistil bicarpellate. Fruit a two-celled capsule dehiscing usually septicidally.

Official drug	Part used	Botanical origin	Habitat
Eriodictyon	Leaves	Eriodictyon californicum	California and New Mexico

Boraginaceæ or Borage Family.—Herbaceous (*Borragineæ* sub-family) or shrubby (*Heliotropeæ* sub-family) plants, forming a primary root and a single or often branched shoots. Leaves often divisible into expanded, sometimes large basal and alternate scattered cauline leaves. Each of these simple, exstipulate, often hairy, rarely glabrous. Inflorescence a raceme of dichesial or scorpioid cymes, at times condensed into a dichesium of scorpioids or a simple scorpioid cyme. Flowers pentamerous, regular, passing to slight or marked irregularity as in Blue-weed (*Echium*); sepals five, green, slightly or deeply gamosepalous, often hairy; petals five, the corolla varying in shape from rotate with shallow tube, as in Forget-me-not (*Myosotis*) and *Borage*, to tubular, as in Comfrey (*Symphy-*

tum), to funnel-shaped in most species; in color, all transitions, frequently purple-blue to blue; stamens five; pistil bicarpellate, syncarpous, embryologically two-celled with two ovules in each cavity,

FIG. 353.—*Atropa Belladonna*—Branch. (*Sayre.*)

but dorsal ingrowths divide ovary by time of flowering into four cells with one ovule in each cavity; style gynobasic. Fruit typically four-nutlets. Seeds solitary in each cavity and either scantily albuminous (*Heliotropeæ*) or exalbuminous (*Borragineæ*).

Unofficial	Part used	Botanical origin	Habitat
Symphytum (Comfrey)	Root	Symphytum officinale	Europe and United States
Cynoglossum (Hound's tongue)	Herb and root	Cynoglossum officinale	United States
Alkanet	Root	Alkanna tinctoria	So. Europe and Asia

FIG. 354.—*Hyoscyamus niger*—Flowering branch. (*Sayre.*)

Solanaceæ or Nightshade Family.—Stem herbaceous, rarely shrubby or arborescent, frequently with bicollateral bundles. Leaves alternate, exstipulate, entire or more or less lobed, rarely compound; often glandular-hairy. Flowers in cymes; regular or rarely irregular (Petunia, Tobacco sps.), pentamerous, perfect, synphyllous; sepals green (rarely petaloid), rotate to tubular, usually persistent and

accrescent; petals rotate (Solanum), to tubular (Atropa), to funnel-shaped (Tobacco), and so (1) open to all comers, or (2) to bees or wasps, or (3) to butterflies, moths; color, greenish-yellow, or greenish-white, to white, to pink, crimson, purple, rarely blue; stamens five, epipetalous, hypogynous, along with style usually forming nectar glands. Filaments short to long, anthers dehiscing longitudinally or by apical pores; pistil bicarpellate, syncarpous, with or without nectar girdle; superior ovary, two-celled with central placentation, ovules numerous, style more or less elongate with bilobed or bifid stigma. Fruit, a capsule (Tobacco, Thornapple, Henbane) dehiscing longitudinally or transversely; or a berry (potato, egg-plant. tomato, red pepper). Seeds albuminous.

Official drug	Part used	Botanical origin	Habitat
Belladonnæ Folia	Leaves and tops	Atropa Belladonna	Central and Southern Europe, Asia Minor and Persia
Belladonnæ Radix	Root	Atropa Belladonna	
Stramonium	Leaves	Datura Stramonium	Asia and Tropical America
Hyoscyamus	Leaves and tops	Hyoscyamus niger	Europe, Asia
Solanum	Ripe fruit	Solanum carolinense	United States
Capsicum	Fruit	Capsicum frutescens	Tropical America
Dulcamara	Twigs and stems	Solanum Dulcamara	Europe and Asia
Manaca	Root	Brunfelsia Hopeana	Tropical America
Unofficial			
Duboisia	Leaves	Duboisia myoporoides	Australia
Tabacum	Leaves	Nicotiana tabacum	Tropical America
Scopola	Rhizome	Scopola Carniolica	Alps and Carpathian Mts.
Paprika	Fruit	Capsicum annuum varieties	America? cultivated
Pimiento	Fruit	Variety of Capsicum annuum	Spain
Miré	Roots, stems and leaves	Brunfelsia hydrangæformis	South America

Scrophulariaceæ or Figwort Family.—Herbs (*Linaria, Verbascum, Gerardia, Digitalis*, etc.), shrubs (shrubby *Veronicas*, etc.), rarely trees (*Paulownia imperialis*). Stem, branches and leaves usually

green and independently vegetating, but in *Pedicularis, Gerardia, Euphrasia, Buchnera, Rhinanthus*, etc., the stem, leaves, and branches are condensed from the development of a parasitic root habit. Stems cylindrical to frequently quadrangular, especially when leaves are opposite. Leaves alternate to opposite and decussate, simple, exstipulate, often hairy, but becoming by drought or parasiticism reduced to scales or almost absorbed. Inflorescence a raceme of cymes (*Paulownia*) or a simple raceme (*Foxglove, Linaria,*

FIG. 355.—Nightshade, or bittersweet (*Solanum Dulcamara*). (*Gager.*)

etc.) or spike (*Verbascum Thapus*) or, if leaves are opposite, often a whorl of axillary flowers or solitary axillary flowers. Flowers rarely regular, mostly irregular; calyx of five sepals, condensed in *Veronica* to four through absorption of one sepal by fusion of two sepals; corolla of five to four petals, deeply synpetalous, varying from rotate (*Verbascum Blattaria*, etc.) to irregular tubular to elongate, irregular bilabiate to funnel-shaped. In color, corolla varies from greenish to greenish-yellow or white (*Scrophularia*) to pure white or from red to purple to blue (*Veronica*). Stamens five, fertile, equal in length in a few *Verbascum* species or unequal in other *Verbascum* species to

stamens four with a long sterile staminode (*Pentstemon*) to four didynamous stamens with a short petaloid staminode (*Scrophularia*) to four didynamous stamens with a minute often nectariferous staminode (*Linaria*), to frequently four didynamous stamens only, the two lateral or two anterior stamens stronger and longer (*Antirrhinum*), to two perfect stamens and two minute staminodes (*Calceolaria*), to two stamens alone developed (*Veronica*). Pistil bicarpellate, ovary two-celled with central placentation; style terminal with bilobed stigma; ovules numerous, small. Fruit a two-celled and usually many-seeded capsule. Seeds richly albuminous, anatropous or amphitropous.

Official drug	Part used	Botanical origin	Habitat
Digitalis	Leaves	Digitalis purpurea	Europe
Leptandra	Rhizome and roots	Veronica virginica	United States and Canada
Verbasci Flores	Corollas with stamens	Verbascum phlomoides Verbascum thapsiforme	Europe and Asia
Verbasci Folia	Leaves	Verbascum Thapsus	Europe and Asia

Pedaliaceæ or Sesame Family.—Tropical herbs often thickly covered with viscous hairs. Leaves soft, usually alternate, more rarely opposite, exstipulate. Flowers irregular, pentamerous. Fruit a capsule (*Sesamum*, etc.), drupe, or rarely a one-seeded, indehiscent nut. Seeds exalbuminous usually.

Official drug	Part used	Botanical origin	Habitat
Oleum Sesami (Benne Oil)	Fixed oil	Sesamum indicum (cultivated varieties)	Asia and Africa

Acanthaceæ or Acanthus Family.—Usually herbaceous (*Ruellia*), rarely sub-woody or woody plants, occasionally bushy in habit, containing cystoliths in the mesophyll or epidermal cells of the leaves and in the parenchyma of the roots and stems. Leaves opposite, more rarely whorled, entire, exstipulate. Inflorescence a raceme of condensed cymes, becoming a simple raceme or spike, rarely con-

FIG. 356.—*Digitalis purpurea* var. *gloxinæflora*.

densed into a solitary terminal inflorescence. Flowers hermaphrodite, usually irregular; calyx five-cleft; corolla hypogynous, gamopetalous, more or less bilabiate, funnel-form and composed of five sepals; stamens usually four (*Ruellia*, etc.), occasionally reduced to two, as in genus *Dianthera*, didynamous or diandrous, epipetalous; pistil bicarpellate; ovary two-celled, superior, with numerous campylotropal ovules; style terminal, filiform. Fruit a capsule containing numerous curved seeds. The family is of pharmaceutic interest mainly because of *Ruellia ciliosa*, a pubescent perennial herb growing in the Eastern United States, whose rhizome and roots have frequently been admixed with or subtituted for Spigelia.

Verbenaceæ or Vervain Family.—Herbs, as the Vervains (*Verbena*), shrubs, as the Glory-bower (*Clerodendron*), rarely trees, as *Premna arborea*, one of the sources of the drug Tonga, and *Tectona* or Teakwood, whose stems and branches are usually quadrangular and rarely scented. Leaves generally opposite, exstipulate, simple or compound. Inflorescence a terminal panicle of spikes (*Verbena hastata*), a cyme (Beauty-berry or *Callicarpa*) or head (*Lippia lanceolata*). Flowers white, pink or blue (*Verbena hastata*), irregular, more or less 2-lipped; calyx gamosepalous, tubular; corolla gamopetalous, hypogynous with a 4–5 fid limb; stamens generally 4, didynamous and inserted on the corolla tube or throat; pistil of 2–4 carpels, a terminal style and undivided stigma. Fruit a drupe or 2 to 4 celled berry, usually splitting into as many nutlets. Seeds exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Tonga	Bark	Premna arborea (in part)	Fiji Islands
Unofficial drug			
Verbena	Overground portion	Verbena hastata	United States

Labiatæ (*Lamiaceæ*) *or Mint Family.*—Herbs producing creeping runners that spread out and root at the nodes. Stems quadrangular, rarely cylindrical in outline. Leaves opposite, decussate, mainly petiolate; leaf margin nearly always serrate, dentate or crenate. Stems and leaves further characterized by the presence of glandular hairs containing aromatic volatile oil. These hairs, for the greater

part, consist of a short one-celled stalk and a head (gland) of six or eight cells. Inflorescence a raceme or spike of verticillasters (double dichesial cymes) or, as in the Ground Ivy, a reduced verticillaster. Flowers typically pentamerous, rarely tetramerous; sepals five,

FIG. 357.—*Mentha piperita*—Flowering branch. (*Sayre.*)

synsepalous, ribbed and forming a tubular regular or irregular bilabiate (Scullcap, etc.) calyx whose upper lip is bifid and lower trifid; corolla of five to four gamopetalous petals, hypogynous, frequently two-lipped, the upper lip bifid, the lower trifid; stamens four, didynamous, rarely one pair alone fertile and the other pair

reduced, in some cases almost or quite to disappearing point, as in the Sage (*Salvia*) and the Horsemint (*Monarda*); pistil bicarpellate, embryologically two-celled with two ovules in each cavity, becoming, at time of flowering, four-celled with one ovule in each cavity. Style embryologically terminal, but, upon opening of flower, deeply gynobasic, elongate, slender, with two stigmatic surfaces. Fruit four nutlets enclosing as many exalbuminous seeds.

Official drug	Part used	Botanical origin	Habitat
Mentha Piperita	Leaves and tops	Mentha piperita	Europe
Oleum Menthæ Piperitæ	Volatile oil from fresh aerial parts of flowering plant	Mentha piperita	Europe
Mentha Viridis	Leaves and tops	Mentha spicata	Europe
Oleum Menthæ Viridis	Volatile oil from fresh aerial parts of flowering plants	Mentha spicata	Europe
Scutellaria	Overground portion	Scutellaria lateriflora	United States and Canada
Oleum Thymi	Volatile oil from flowering plant	Thymus vulgaris	Southern Europe
Oleum Rosmarini	Volatile oil from fresh flowering tops	Rosmarinus officinalis	Mediterranean Basin
Oleum Lavandulæ	Volatile oil from fresh flowering tops	Lavandula Spica	Southern Europe
Cataria	Leaves and flowering tops	Nepeta Cataria	Europe and Asia
Unofficial			
Salvia	Leaves	Salvia officinalis	Southern Europe
Marrubium	Leaves and flowering tops	Marrubium vulgare	Europe and Asia
Hedeoma	Leaves and flowering tops	Hedeoma pulegioides	United States and Canada
Herba Majoranæ	Leaves and flowering tops	Origanum Majorana	Mediterranean regions
Collinsonia	Rhizome and roots	Collinsonia canadense	United States
Serpyllum	Leaves and flowering tops	Thymus Serpyllum	Europe and Asia

Unofficial	Part used	Botanical origin	Habitat
Melissa	Leaves and flowering tops	Melissa officinalis	Southern Europe, Asia Minor
Monarda	Leaves and flowering tops	Monarda punctata	United States
Origanum	Leaves and flowering tops	Origanum vulgare	Europe, Asia and North Africa
Hyssopus	Leaves and flowering tops	Hyssopus officinalis	Southern Europe
Summer Savory	Leaves	Satureia hortensis	Southern Europe
Mountain Mint	Leaves	Pycnanthemum Montanum	United States
Sweet Basil	Leaves	Ocimum Basilicum	Asia and Africa
Motherwort	Leaves and flowering tops	Leonurus Cardiaca	Europe

ORDER RUBIALES

Rubiaceæ or Madder Family.—Herbs, as Cleavers (*Galium*) and Partridge Berry (*Mitchella*), etc., shrubs as the Ipecac (*Cephaëlis*) and the Buttonbush (*Cephalanthus*), or trees (*Cinchona* species) with fibrous roots, sometimes, as in *Cephaëlis Ipecacuanha*, annularly enlarged. Roots, stems and to a less extent leaves rich in varied alkaloids, some of medicinal value. Leaves opposite, entire, stipulate and interpetiolate. Inflorescence a raceme of dichesial cymes, occasionally condensing to scorpioids. Flowers perfect, often dimorphic, pentamerous or tetramerous; sepals five (*Cinchona*, etc.) but four in *Galium*, small, green, subtended with other flowers by one or two or more enlarged petaloid bracts; petals five (*Cinchona*, etc.) to four in *Galium*, stellate, varying from shallow-rotate to elongate-tubular or funnel-shaped with stellate limbs; stamens five to four, epipetalous; pistil nearly always bicarpellate, rarely of five to four carpels; ovary inferior, two-celled with central placentation; styles either distinct with knob-shaped stigmas or style elongate, filiform, ending in bilobed stigmas. Fruit varied, a capsule in *Cinchona*, a berry in *Coffee*, a drupe, or frequently, as in *Galium*, dry and splitting into nutlets; seeds albuminous, each with a curved embryo.

Official drug	Part used	Botanical origin	Habitat
Caffeina	Feebly basic principle	Coffea arabica	Eastern Africa
		Coffea liberica	Liberia
Cinchona	Bark	Cinchona succirubra or its h brids	South America
		Cinchona Ledgeriana, C. Calisaya and hybrids of these with other Cinchona species	
Coffee Tosta	Roasted seeds	Coffea arabica	Africa
		Coffea liberica	
Gambir	Prepared aqueous extract from decoctions of leaves and twigs	Ourouparia Gambir	Malay Archipelago
Ipecacuanha	Rhizome and root	Cephaëlis Ipecacuanha	Brazil
		Cephaëlis acuminata	United States of Columbia
Mitchella	Entire plant	Mitchella repens	North America

Caprifoliaceæ or Honey Suckle Family.—Shrubs (Elder, Viburnum, Snowberry, etc.) or rarely herbs (Twin Flower). Leaves entire, opposite, exstipulate or with delicate, attenuate or filiform stipules. Inflorescence varying from a raceme of shortened cymes to a capitulum. Flowers varying from regular and small (*Sambucus*, *Viburnum*, etc.) to increasingly large, slightly irregular and ultimately very irregular, in some Honeysuckles (*Lonicera*) and in a few *Weigelas* and allies; calyx pentamerous, superior; corolla superior, gamopetalous, limb pentafid, small in *Viburnum* and *Sambucus* to elongate-tubular or irregular-infundibuliform in Honeysuckles; stamens five, inserted on tube of corolla and alternating with corolla segments; filaments equal or didynamous (in irregular flowers); ovary inferior, rarely five- to three-celled, usually three- or frequently two-celled; style terminal. Fruit a berry (*Honeysuckle*, *Elder*, etc.) from an inferior ovary, several celled, occasionally becoming one-celled with several to rarely one seed and drupaceous (*Viburnum*) or fruit a capsule (*Diervilla*, *Weigelia*). Seeds albuminous.

Official drug	Part used	Botanical origin	Habitat
Sambucus	Flower (air-dried)	Sambucus canadensis	United States
		Sambucus nigra	Europe
Viburnum Prunifolium	Bark of root	Viburnum prunifolium	Eastern and central United States
Viburnum Opulus	Bark	Viburnum Opulus var. Americanum	United States and Canada

FIG. 358.—*Cephaëlis Ipecacuanha*—Plant and dried root. (*Sayre.*)

ORDER CUCURBITALES

Cucurbitaceæ or Gourd Family.—Herbaceous, very often annual (*Colocynth*, etc.), more rarely perennial (*Bryonia*, etc.), sometimes shrubby plants, the perennial and shrubby forms perennating by swollen roots, some of which are heavy and tuberous. Stems very usually grooved and ridged, often provided with roughened and barbed hairs. Tendrils are frequently produced in the axils of leaves from tendril axillary buds (Pumpkin, Colocynth, Watermelon, Cucumber, Bryony, etc.). Leaves varying from entire, simple, usually deltoid to triangular through stages of trilobate, pentalobate, deeply palmatifid to palmatipartite to seldom approaching compound (Colocynth). Venation in nearly all cases palmate. Leaves thin, herbaceous, much expanded, often hairy. Vascular bundles of petioles, branches and stems, bicollateral. Inflorescence either of loose cymes or more frequently racemes or spikes or entire axillary inflorescence may become solitary axillary. Flowers pentamerous, very rarely tetramerous, monœcious (*Bryonia alba*) or dicœcious (*Bryonia dioica*); sepals five, gamosepalous, adnate to ovary; corolla of five, rarely four gamopetalous petals varying in size and shape from small to large campanulate or broadly cup-shaped (Cucumber) and in color from greenish-yellow to greenish-white to pure yellow to yellowish-white to white; stamens typically five, epigynous, with anthers either joined by pairs or synantherous; carpels usually three; ovary inferior, one- to three-celled. Fruit a pepo (a berry from an inferior ovary with thick skin). Seeds flat and exalbuminous.

FIG. 359.—Colocynth—Portion of vine and whole fruit. (*Sayre.*)

Official drug	Part used	Botanical origin	Habitat
Bryonia	Root	Bryonia alba Bryonia dioica	Europe

FIG. 360.—*Valeriana officinalis*—Plant and rhizome. (*Sayre.*)

Colocynthis	Pulp of fruit	Citrullus Colocynthis	Africa and Asia

Official drug	Part used	Botanical origin	Habitat
Pepo	Seed	Cucurbita Pepo (cultivated varieties)	Probably Tropical America
Elaterinum	Principle from elaterium	Ecballium Elaterium	Mediterranean region
Unofficial			
Watermelon Seed	Seeds	Citrullus vulgaris	Southern Asia
Momordica (Balsam apple)	Fruit	Momordica Balsamina	East Indies

ORDER VALERIANALES

This order includes the *Valerianaceæ* or Valerian Family and the *Dipsaceæ* or Teasel Family. Both are represented by herbs with flowers having an inferior ovary containing a single ovule.

Valerianaceæ or Valerian Family.—Herbaceous often low succulent plants with creeping rhizomes, frequently strongly scented and possessing stimulating properties. Leaves frequently dimorphic; radical fascicled; cauline opposite; petiole dilated, exstipulate. Inflorescence a raceme of dichesial or scorpioid cymes. Flowers more or less irregular; calyx absent as such, but represented by a series of teeth that are incurved in the bud and flower and which expand later into a pappose crown and act in the fruit as a pappose disseminator; corolla pentamerous, gamopetalous, varying from rotate-synpetalous to irregular-tubular with petals diversely united, in color varying from greenish-white to white or pink (*Valeriana officinalis*) to crimson; stamens three to two or one (*Valerian*), epipetalous; pistil syncarpous; ovary usually one-celled, inferior; style filiform with three stigmatic surfaces. Fruit an akene from inferior ovary crowned by a persistent, expanded, pappose calyx rudiment. Seeds anatropous, exalbuminous.

Official drug	Part used	Botanical origin	Habitat
Valeriana	Rhizome and roots	Valeriana officinalis	Europe and Asia

ORDER CAMPANALES (CAMPANULALES)

This order comprises the Bluebell Family (*Campanulaceæ*), the Lobelia Family (*Lobeliaceæ*) and the Daisy Family (*Compositæ*).

Its outstanding characters are the epigynous corolla, usually 5 stamens and inferior ovary with a three- to two-cleft stigma.

Campanulaceæ or Bluebell Family. Herbs of annual or more commonly perennial growth rarely sub-shrubby or sub-woody in habit, frequently with laticiferous tubes containing a milky juice. Stem upright or feeble and spreading. Leaves alternate, simple, exstipulate. Inflorescence primitively a racemose cyme condensing into a raceme, to a sub-capitulum and ultimately to a capitulum. Flowers regular, campanulate to campanulate-elongate to elongate and deeply cleft in petals; sepals five, only slightly synsepalous, epigynous; petals five, campanulate to campanulate-tubular to tubular-elongate to tubular and deeply cleft; corolla varying in color from greenish-yellow to yellowish-white to white or again, from yellowish-purple (rarely through yellowish-pink or red) to purple to pure blue; stamens five, epigynous, usually free from corolla; nectary epigynous; pistil usually tricarpellary; ovary as many celled as number of carpels and with central placenta; style single, elongate; stigmas as many as carpels. Fruit a capsule. Seeds albuminous. The plants contain inulin.

Lobeliaceæ or Lobelia Family.—Herbs, with inulin and latex contents, corresponding with *Campanulaceæ* in their vegetative parts, but differing from that group by having irregular flowers (pale blue in *Lobelia inflata*), anthers always united into a tube (synantherous) and pistil always bicarpellate with two-celled ovary and bilobed or bilabiate stigma.

Official drug	Parts used	Botanical origin	Habitat
Lobelia	Leaves and flowering tops	Lobelia inflata	United States and Canada

Compositæ (Asteraceæ) or Daisy Family.—Herbs of annual or perennial habit, rarely shrubs or trees, and with watery or milky juice. Inulin is present in cell sap of parenchyma. Leaves alternate, rarely opposite, simple to compound, exstipulate. Inflorescence a capitulum or a raceme of capitula, each capitulum surrounded by an involucre or protective whorl of bracts, and composed of numerous small flowers called florets that may be: (*a*) wholly

regular, tubular and hermaphrodite (Thistle, etc.); or (*b*) central florets as in (*a*), but marginals strap-shaped or ligulate and usually pistillate (Daisy, Dahlia, etc.); or (*c*) florets all ligulate and hermaphrodite (Dandelion, Chicory, etc.); or (*d*) florets in part or in whole bilabiate (Mutisia, etc.). Flowers small (florets), closely crowded, pentamerous, shaped as above, with ovary inferior and other floral

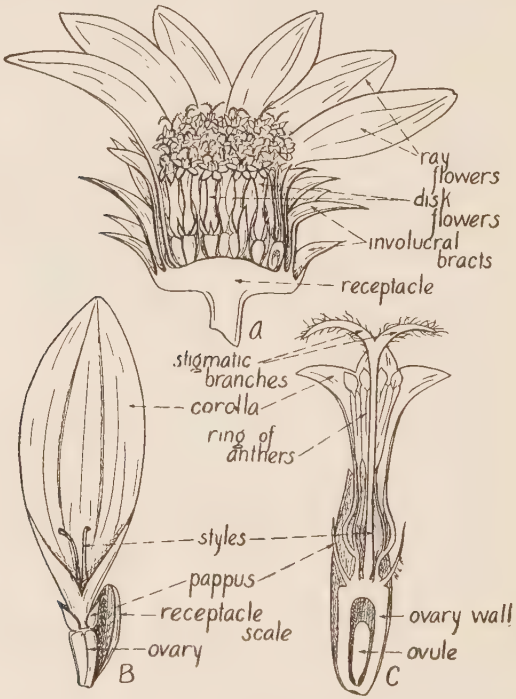

FIG. 361.—Capitulum of a composite. Jerusalem artichoke (*Helianthus tuberosus*). *A*, lengthwise section of capitulum, × 1; *B*, ray flower, × 6; *C*, disk flower, cut lengthwise, × 6. (*A after Baillon, B* and *C, Robbins.*)

parts superior. Sepals rudimentary, tooth-like (Sunflower), or reduced to a pappose or hairy rudiment above the ovary that is functionless during flowering, but that expands in fruit as a hairy fruit disseminator (Dandelion, Thistle, etc.); or sepals wholly

absorbed (Daisy). Petals synpetalous, tubular, ligulate or rarely bilabiate, greenish-yellow to white, or through pink-crimson and purple to blue (Chicory). Stamens five, epipetalous, filaments

Fig. 362.—*Matricaria Chamomilla*—Branch and dissected flowers. (*Sayre.*)

distinct, anthers united into an upright anther-box (so synantherous) into which pollen is shed before or during opening of each floret. Carpels two, syncarpous; ovary inferior, one-celled with single

ovule; style simple, at first short, later elongating and by collecting hairs sweeping pollen to top of anther box, then dividing into two stigmatic surfaces with stigmatic hairs for pollen reception. Fruit an indehiscent achene, often (Dandelion, Thistle) crowned by the pappose, calyx rudiment. Seed single, exalbuminous.

The Compositæ is subdivided into two sub-groups or series, namely the *Tubuliflorœ* and the *Liguliflorœ*. The **Tubuliflorœ** include all those Composites whose flower heads contain either tubular florets only, as the Eupatoriums and Burdocks or marginal ligulate florets and central tubular florets, as in the Sunflower, Chamomiles, etc. The **Liguliflorœ** include those Composites whose flower heads possess ligulate florets only, as the Dandelions, Hawkweeds, Chicory, Lettuces, etc. They contain a bitter or acrid milk juice.

Official drug	Part used	Botanical origin	Habitat
Arnica	Flower head	Arnica montana	Europe
Matricaria	Flower head	Matricaria Chamomilla	Europe and western Asia
Calendula	Ligulate florets	Calendula officinalis	Mediterranean basin
Senecio	Entire plant	Senecio aureus	United States
Eupatorium	Leaves and flowering tops	Eupatorium perfoliatum	North America
Grindelia	Leaves and flowering tops	Grindelia camporum Grindelia cuneifolia Grindelia squarrosa	Western North America
Inula	Rhizome and roots	Inula Helenium	Europe and Asia
Taraxacum	Rhizome and roots	Leontodon Taraxacum	Europe
Echinacea	Rhizome and roots	Brauneria pallida Brauneria angustifolia	Central United States
Lappa	Root of first year plant	Arctium Lappa and Arctium minus	Europe and Asia
Farfara	Leaves	Tussilago Farfara	Europe
Santoninum	Inner anhydride of santoninic acid	Artemisia Cina	Turkestan

Unofficial	Part used	Botanical origin	Habitat
Anthemis	Flower head	Anthemis nobilis	Europe
Pyrethri Flores	Flower head (unexpanded or partly expanded)	Chrysanthemum cinerariifolium	Dalmatia Herzegovina
		Chrysanthemum roseum	
		Chrysanthemum Marschallii	Western Asia

FIG. 363.—Chicory (*Cichorium Intybus*). *A*, portion of flowering branch; *B*, basal leaf (runcinate-pinnatifid); *C*, median longitudinal section through a head showing the insertion of the flowers; *D*, individual flower; *E*, fruit (ripened ovary), showing the persistent pappus (calyx) of short scales. (*Gager.*)

Pyrethrum	Root	Anacyclus Pyrethrum	Northern Africa and southern Europe

Unofficial	Part used	Botanical origin	Habitat
Absinthium	Leaves and flowering tops	Artemisia Absinthium	Europe, Asia and Africa
Lactucarium	Dried milk juice	Lactuca virosa	Europe
Santonica	Unexpanded flower head	Artemisia Cina	Turkestan
Carthamus	Tubular florets	Carthamus tinctorius	India
Achillea	Leaves and flowering tops	Achillea millefolium	Europe and Asia
Tanacetum	Leaves and flowering tops	Tanacetum vulgare	Europe
Gnaphalium	Leaves and flowering tops	Gnaphalium polycephalum	North America
Cichorium	Rhizome and roots	Cichorium Intybus	Europe
Oleum Erigerontis	Volatile oil	Erigeron canadensis	North America

CHAPTER XXIV

THE MONOCOTYLEDONS

This is a class of Angiosperms characterized by the following peculiarities:

One cotyledon or seed leaf in the embryo, terminal in position.

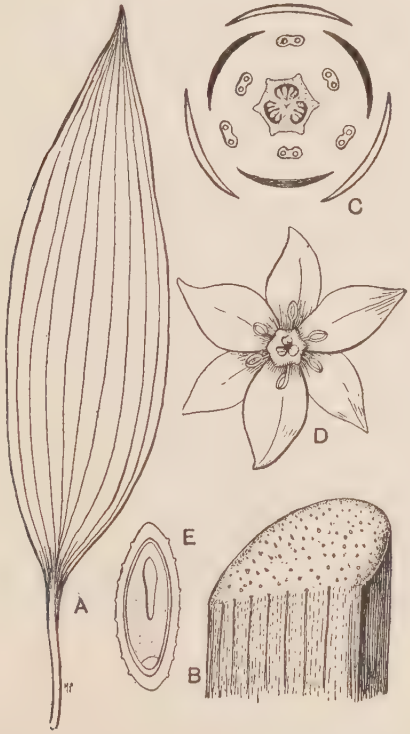

FIG. 364.—Morphology of the typical monocotyledonous plant. *A*, leaf, parallel-veined; *B*, portion of stem, showing irregular distribution of vascular bundles; *C*, ground plan of flower (the parts in 3's); *D*, top view of flower; *E*, seed showing monocotyledonous embryo. (*Gager.*)

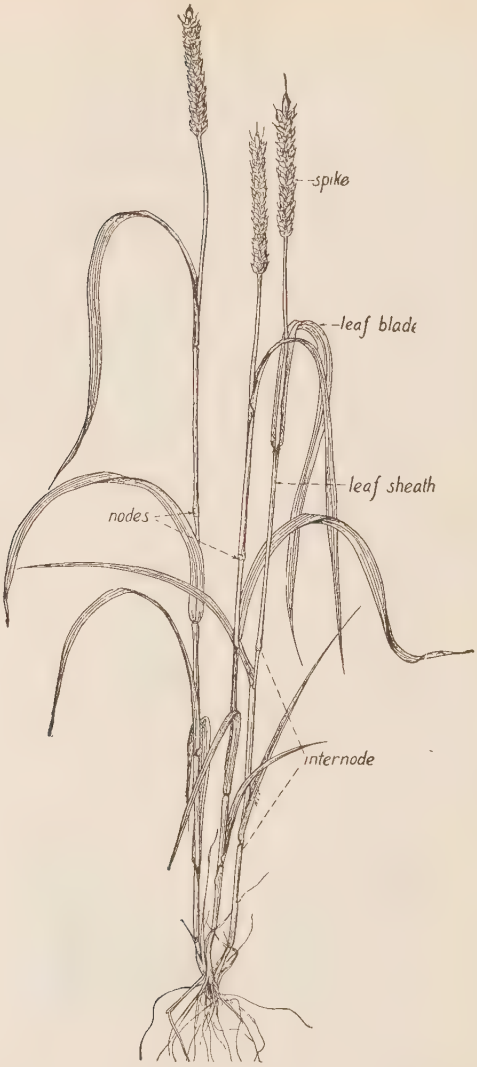

FIG. 365.—Wheat plant showing the general habit of grasses. (*Robbins.*)

Stems endogenous with closed collateral or concentric fibro-vascular bundles, which are scattered.

Leaves generally parallel-veined.

FIG. 366.—Pistillate and staminate inflorescences of corn (*Zea mays*). Pistillate on left, staminate on right. (*Robbins.*)

Flowers trimerous (having the parts of each whorl in threes or a multiple thereof.)

Secondary growth in roots generally absent.

Medullary-rays generally absent.

DRUG YIELDING GROUPS OF MONOCOTYLEDONS

The Monocotyledons comprise 45 families which contain about 25,000 species of described plants. Only those groups which yield drugs are considered in this chapter.

ORDER GRAMINALES

This is the most important economic order of Monocotyledons. It contains two families, the *Gramineæ* or family of grasses and cereals and the *Cyperaceæ* or family of sedges. The flowers of both of these families are devoid of sepals and petals but possess scale-like structures called glumes and palets which enclose one or more flowers.

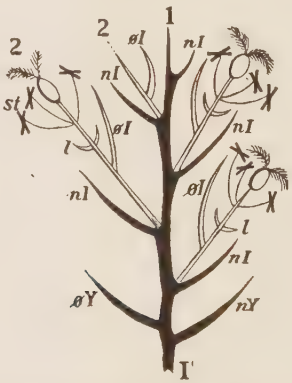

FIG. 367.—Diagram of a typical spikelet. *nY* lower glume; *øY* upper glume; *nI* outer palet; *ΦI*, inner palet; *l*, lodicule; *st*, stamens; *I-I*, rachilla; 2, lateral axes. (*Somewhat modified after Warming.*)

The grasses and cereals have stems with solid nodes and hollow internodes whereas the sedges have stems which are solid throughout. The above ground stem of a sedge is usually 3-sided, unlike any grass stem.

Gramineæ or Grass Family.—Mostly herbaceous (*Triticum*, *Sorghum*, *Saccharum*, cereals, etc.), rarely shrubby (*Arundinaria*, etc.), more rarely arborescent (Bamboo, etc.) plants, varying in height from 2 in. to 100 ft.

Stems, leaves and even parts of flowers often abounding in silica. The leaves are alternate, with long split sheaths and a ligule. Flow-

ers small, generally hermaphroditic, occasionally monœcious (Corn and Rice Grass) and usually borne in *spikelets* arranged along a spike-axis called a rachis, but sometimes in panicles (Oat). The spikelet is the unit of a grass inflorescence. A typical spikelet consists of a shortened axis (*rachilla*) bearing floral leaves. The two lowest floral leaves in each spikelet are barren and termed *glumes*. The succeeding floral leaves are of bract-like character, each supporting one flower in its axil, and are called *outer palets* or *lemmas*. Each flower has a bracteole which is placed on the inside, opposite and with its back to the rachilla and known as the *inner palet*. Immediately following the inner palet are 2 delicate scales called *lodicules*, 3 *stamens* with versatile anthers that are usually notched at each end and a single *pistil* of one carpel, having a unilocular ovary with one ovule and 2 styles, with simple or spirally branched stigmas. Fruit, a caryopsis or grain. Seeds albuminous with starchy endosperm and a small embryo at the base and opposite the hilum side. Seed coat fused with fruit coat to form one layer. Embryo with a *scutellum*. The scutellum represents a portion of the single cotyledon of these plants, which bales out the nourishment from the endosperm to the rest of the embryo, during the germination of the grain.

Official drug	Part used	Botanical origin	Habitat
Triticum	Rhizome and roots	Agropyron repens	Europe and Asia
Sucrosum	Refined sugar	Saccharum officinarum and other sources	Tropics
Maltum	Grain, partially germinated and dried	Var. of Hordeum vulgare	Asia
Amylum	Starch	Zea Mays	Mexico
Zea	Styles and stigmas	Zea Mays	Mexico
Avena Sativa	Grain	Avena sativa	Eurasia

ORDER PRINCIPES

Palmæ or Palm Family.—Tropical or subtropical shrubs, rarely trees, having unbranched trunks which are terminated by a crown of leaves, in the axils of which the flowers are produced. The leaves

FIG. 368.—Cocoanut Palm (*Cocos nucifera*). Note pinnate leaf-blades. (*From Bull. Agricole du Congo Belge.* 1910.)

are well developed with pinnate or palmate blades and fibrous, sheathed, clasping petiole. The flowers are small, of one or two sexes, and crowded on a spike or spadix, which is subtended by a large bract, or spathe which may become woody, as in the Cocoanut Palm. The perianth consists of 6 parts in 2 whorls (3 sepals and 3 petals) or it may be inconspicuous or absent. The stamens are 6 in number, rarely 3, inserted below the ovary. The ovary is superior, of 3 cells, with central placenta. The fruit is either a nut, with leathery epicarp, fibrous or cellular mesocarp and thin membranous endocarp, or a drupe (Cocoanut) with leathery epicarp, broadly fibrous mesocarp and stony endocarp, or a berry as in the Date Palm, *Phoenix*, with membranous epicarp, succulent mesocarp and soft succulent endocarp. The seeds are albuminous with the reserve food frequently in the form of hard (reserve) cellulose (ivory-nut-palm.)

Official drug	Part used	Botanical name	Habitat
Sabal	Fruit (drupe)	Serenoa serrulata	South Carolina to Florida and Texas
Unofficial			
Dragon's Blood	Inspissated juice	Dæmonorops Draco	East Indies
Cocoanut oil	Fixed oil	Cocos nucifera	Tropics
Carnauba wax	Wax from leaves	Copernicia cerifera	Brazil
Areca nut	Seed	Areca Catechu	Asia and Malay Islands
Palm oil	Fixed oil	Elæis guineensis	West Africa

ORDER ARALES

Araceæ or Arum Family.—Perennial herbs with fleshy rhizomes or corms, long petioled leaves, and acrid or pungent juice. Flowers usually imperfect, rarely hermaphroditic, the pistillate usually below, the staminate above, crowded on a spadix, which springs from the axil of a spathe. Fruit an indehiscent, 1-several celled, 1-many seeded berry. Seeds filled with large fleshy embryo or containing an embryo and mealy or fleshy albumen.

Official drug	Part used	Botanical name	Habitat
Tonga	Root	Epipremnum pinnatum (in part)	Fiji Islands
Unofficial drugs			
Calamus	Unpeeled rhizome	Acorus Calamus	Europe, Asia, North America
Skunk cabbage	Rhizome	Symplocarpus fœtidus	North America
Indian turnip	Corm	Arisæma triphyllum	North America

FIG. 369.—Saw palmetto. This palm, which appears in the center of the figure, yields the official drug, sabal. In the right distance a barragona palm. Cuba. (*Gager.*)

ORDER LILIALES

Liliaceæ or *Lily Family.*—Herbs (*Lilium*), shrubs (*Yucca*), or trees (*Dracena Draco* or Dragon's Blood), with regular and symmetrical almost always six-androus flowers. Stem either short, creeping under ground (*Convallaria*), or, swelling up and forming bulbs

(Hyacinth), or corms (*Colchicum*), or, stem may elongate above ground and become wiry and herbaceous or semi-shrubby as *Smilax*, or the stem may remain short, giving rise to thick fleshy and sap-storing leaves, as in *Aloe*. Leaves linear to lanceolate, ovate

FIG. 370.—*Acorus calamus*, The Sweet flag a member of the *Araceæ*. (*Sayre.*)

rarely wider, divisible into sheating base, narrow petiole and expanded blade. Venation, parallel, becoming in some ovate leaves parallel with oblique connections, reticulate or highly reticulate, as in the Sarsaparilla plants and other species of *Smilax*. The perianth is

parted into six segments, the calyx and corolla being alike in color. Anthers introrse. Ovary three-locular with a single style. Fruit a three-locular, loculicidally dehiscent capsule (*Lilium*, etc.) or rarely a berry (*Asparagus*, etc.). Seeds usually numerous with fleshy endosperm.

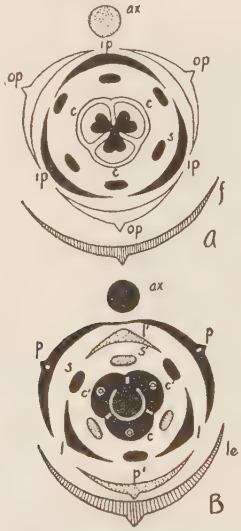

FIG. 371.—Diagram of *A*, lily flower, and *B*, grass flower, showing homologous structures. *A*, *f*, bract; *ax*, axis; *op*, outer perianth; *ip*, inner perianth; *s*, stamens; (*c*) tricarpellary ovary. *B*, shaded structures are aborted; *le*, lemma (bract); *ax*, axis; *p* and *p'*, palet (outer perianth); *l* and *l'*, lodicules (inner perianth); *s* and *s'*, two whorls of stamens; *c*, tricarpellary ovary. (*A*, *Robbins*. *B*, *after Shuster*.)

Official drug	Part used	Botanical name	Habitat
Sarsaparilla	Root	Smilax medica	Mexico
		Smilax ornata	Costa Rica
		Smilax officinalis or an undetermined species	Guatemala, Honduras and Nicaragua
Veratrum Viride	Rhizome and roots	Veratrum viride	United States
Colchici Cormus	Corm	Colchicum autumnale	Mediterranean Basin
Colchici Semen	Seed	Colchicum autumnale	Mediterranean Basin

Official drug	Part used	Botanical name	Habitat
Aloe	Inspissated juice of leaves	Aloe vera	Dutch West Indies
		Aloe Perryi	Socotra and East Africa
		Alœ ferox	South Africa

FIG. 372.—*Smilax officinalis*—Portion of vine and rhizome. (*Sayre.*)

Official drug	Part used	Botanical origin	Habitat
Scilla	Inner scales of bulb	Scilla maritima (Urginea maritima)	Mediterranean Basin
Veratrina	Mixture of alkaloids	Asagræa officinalis	Mexico and Central America
Convallariæ Radix	Rhizome and roots	Convallaria majalis	Europe, Asia, United States
Convallariæ Flores (unofficial)	Inflorescence		
Trillium	Rhizome and roots	Trillium erectum	North America
Allium	Bulb (fresh)	Allium sativum	Southern Europe
Aletris	Rhizome and roots	Aletris farinosa	Eastern United States
Helonias	Rhizome and roots	Chamælirium luteum	Eastern United States

Dioscoreaceæ or *Yam Family.*—Twining perennial herbs or undershrubs arising from large tuberous roots or knotted rootstocks. Leaves alternate, petioled, simple, palmately-ribbed and netted-veined. Flowers small, diœcious, regular, having a six-cleft calyx-like perianth, six stamens and a three-celled inferior ovary. Fruit usually a membranous, three-angled or winged, three-celled capsule.

Official drug	Part used	Botanical name	Habitat
Dioscorea	Rhizome	Dioscorea villosa	United States

Iridaceæ or Iris Family.—Perennial herbs with equitant two-ranked leaves and regular or irregular flowers which are showy. Fruit a three-celled, loculicidal, many-seeded capsule. Rootstocks, tubers, or corms mostly acrid. Fibrovascular bundles concentric.

Official drug	Part used	Botanical name	Habitat
Iris	Peeled rhizome	Iris florentina Iris pallida Iris germanica	Mediterranean Region
Iris Versicolor	Rhizome	Iris versicolor Iris caroliniana	Eastern North America
Crocus	Stigma	Crocus sativus	Southern Europe and Asia

ORDER SCITAMINALES

This order includes herbs with asymmetrical flowers and pinnately-veined leaves. Some of the members, notably the bananas, are gigantic in size. It contains the *Musaceæ* or Banana Family.

Cannaceæ or Canna Family, *Zingiberaceæ* or Ginger Family and *Marantaceæ* or Arrowroot Family.

Zingiberaceæ or Ginger Family.—Tropical plants, perennial herbs, usually with fleshy rhizomes and large elliptical pinnately-veined

FIG. 373.—*Zingiber officinale.* (*Sayre.*)

leaves. The leaf sheaths are folded tightly around each other so as to give the appearance of a stem. Flowers, very irregular, trimer-

ous; sepals three short, often green; petals three, elongate, often fused below; stamens three to four abortive, petaloid, one often absent, a sixth alone fertile and stamen-like. The petaloid stamens constitute the most attractive parts of the flower. Pistil, inferior,

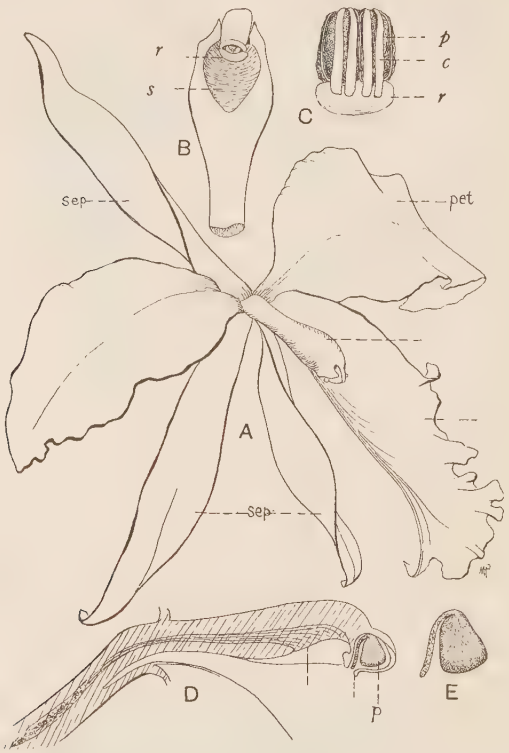

FIG. 374.—Floral organs of an orchid (*Catleya sp.*). *A*, the entire flower; *sep*, sepal; *pet*, petal; *B*, column, showing *s*, stigma and *r*, the rostellum (beak), with the small glands at the tip; to the glands are attached the four strap-shaped caudicles of the pollinia; *C*, pollinia, with the four caudicles; below, the gland; *D*, longitudinal section of the column; *p*, pollinium; *E*, the same, enlarged. (*Gager.*)

tricarpellary. Fruit, a loculicidally dehiscent, usually 3-celled capsule. Seeds albuminous with both perispermic and endospermic albumen.

Official drug	Part used	Botanical name	Habitat
Zingiber	Rhizome	Zingiber officinale	S. Asia
Cardamomi Semen	Seeds	Elettaria Cardamomum	Indo-China
Oleum Cardamomi	Volatile oil from seeds	Elettaria Cardamomum	Indo-China
Galanga	Rhizome	Alpinia officinarum	China
Zedoaria	Rhizome	Curcuma Zedoaria	India
Unofficial drug			
Curcuma	Prepared rhizome	Curcuma longa	S. Asia and E. Indies
Grains of Paradise	Seeds	Amomum grana paradisi Amomum melegueta	Asia

Marantaceæ or Arrowroot Family.—Perennial herbs chiefly of tropical climes with fleshy rhizomes or tubers rich in starch content. The leaves are radical and cauline, usually long petioled, with a sheathing base and a pulvinus at the summit of the petiole. The inflorescence is a panicle or raceme bearing irregular trimerous flowers with a one-celled ovary (by abortion).

Unofficial drug	Part used	Botanical origin	Habitat
Amylum Marantæ	Starch	Maranta arundinacea	West Indies Northern S. America

ORDER ORCHIDALES

Orchidaceæ or Orchid Family.—Perennial herbs of terrestrial or terrestrial saprophytic or epiphytic growth, having grotesque flowers. Roots fibrous or tuberous, often saprophytic in relation, or aerial and with velamen. Stems and branches upright, in epiphytic types, often forming pseudobulbs. Leaves alternate, entire, parallel-veined, sheathing at base, rarely reduced to yellowish or pale scales in saprophytes. Flowers irregular, usually attractive, entomophilous, arranged in elongated spikes or racemes, trimerous. Sepals three, usually similar; petals three of which two often resemble

sepals, third is variously, often greatly modified and fused with two outer petaloid stamens as a labellum or lighting-board for insects. Third stamen of outer whorl fertile (*Orchideæ*) or a barren knob (*Cypripediæ*); pollen of fertile anther agglutinate as pollinia. Three

FIG. 375.—*Vanilla planifolia*—Branch showing leaves and flowers. (*Sayre.*)

stamens of inner circle barren and petaloid or one absent (*Cypripediæ*). Stamens all epigynous and often three are fused with the style as gynandrium. Carpels three, syncarpous, with inferior, three-, rarely four-, one (usually)-celled ovary. Fruit a capsule, three-valved and one-celled. Seeds minute, abundant and wind disseminated.

Official drug	Part used	Botanical name	Habitat
Vanilla	Fruit (cured, full-grown, unripe)	Vanilla planifolia	Mexico
Cypripedium	Rhizome and roots	Cypripedium bulbosum Cypripedium parviflorum Cypripedium pubescens	United States
Unofficial drug			
Salep	Tubers	Orchis mascula Orchis morio	Europe
Corallorhiza	Rhizome	Corallorhiza odontorhiza	Eastern U. S.

CHAPTER XXV

ECOLOGY

Ecology is that department of biology which deals with the relations of plants and animals of various habitats to their environmental conditions. Every living thing is a creature of circumstance, dominated and controlled by heredity and environment. In order to exist and keep healthy it must adapt itself to the various factors of its surroundings. The environmental factors having to do with the existence and health of plants include soils and soil constituents, air, moisture, light, range in temperature, gravity, and surrounding animals and plants of other kinds.

PLANT ASSOCIATIONS

A group of plants occurring in a common habitat constitutes what is termed a plant association or society. Plant associations may be classified either from the point of view of their order of development, as based upon the principle of succession, or upon their water relation. The latter method appears to be the one more generally adopted, because of its ready application, and will now be considered.

According, therefore, to the relation plant associations have assumed in regard to water, they may be grouped as follows:

1. *Hydrophytes* or water plants.
2. *Helophytes* or marsh plants.
3. *Halophytes* or salt plants.
4. *Xerophytes* or desert plants.
5. *Mesophytes* or intermediate plants.
6. *Tropophytes* or alternate plants.

Hydrophytes.—The effect of an aquatic environment on the structure of water plants is most striking. The root systems are reduced both in length and number of branches. The root hairs of those immersed in the water are absent. The supportive action of the

water is such that the fibrovascular elements of the stems, which usually function both for support and conduction of crude sap, are greatly reduced in size and strength. The leaves, stems and roots possess large air-spaces. The mesophyll of the leaves is spongy and the chloroplasts motile. Stomata are entirely absent from leaves that are submerged and only present on the upper surface of floating ones, where they are nearly always open. Some of these plants have broad floating leaves and dissected submerged ones, often with thread-like divisions. The submerged parts are devoid of special protective walls, *e.g.*, those containing cutin or suberin. The cell sap has a low osmotic pressure. The submerged leaves often absorb more water than the roots. The free floating microscopic plants (blue-green algæ, bacteria, diatoms, desmids, etc.) form the *plankton* of our ponds, rivers and lakes. The free-swimming higher plants (the *pleuston*) comprise certain liverworts like *Riccia* and *Ricciocarpus*, water-ferns and such seed plants as the water-lettuce and water-hyacinth. The aquatic plants, including the algæ, mosses and flowering plants, which live attached to rocks comprise the *lithophilous benthos*. Another class of aquatic plants (*benthos*) include those with true roots, which attach the plant to the substratum, and at most possess floating leaves. This type includes the water-lilies, the water-chestnut, the splatter docks, the floating-heart and the pondweeds.

Helophytes.—To this group belong plants typical to marshes. A marsh is an area with wet soil, wholly or partially covered with water and with annual or perennial herbs (never shrubs and trees) which are adjusted structurally to a mucky soil, lacking the usual supplies of oxygen. These plants likewise show an adjustment to a partial or periodical submergence. Like hydrophytes, marsh plants are for the most part perennial. They produce adventitious roots and possess horizontal rhizomes, or runners, and frequently have air chambers in roots, stems and leaves, so that they are adapted to meet the scarcity of air in wet soils. They also show a striking development of erect chlorophyll-bearing organs in the shape of leaves, in the flags, and stems, in the rushes.

The taller seed-like plants of the marsh-land, such as seed-grass (*Phragmites*), the bur-reed (*Sparganium*), the cat-tails (*Typha*), the

blue flags (*Iris*), the sweet flag (*Acorus calamus*) and the papyrus (*Papyrus*) form associations known as fresh-water marshes, reed-marshes or fens. The channels or pools of water in amongst these amphibious plants are filled with true aquatic plants.

Halophytes.—The plants of this group live in a soil which is rich in soluble salt, usually common salt (NaCl), and, on account of the fact that the osmotic force of the root is nearly inadequate to overcome that of the concentrated solution of the soil, the soil to such plants is physiologically dry. A halophyte, in fact, is one form of xerophyte. The most striking feature among halophytes is that they are nearly all succulent plants. The leaves of such plants, for example, are thick, fleshy and more or less translucent. They are rich in concentrated cell sap by which they are able to counteract the osmotic pull of the concentrated saline solution of the soils in which they live. Anatomically they are poor in chlorophyll; the intercellular-air-spaces are small and the palisade tissue is more abundant. Coatings of wax are found and a hairy covering, although infrequent, sometimes occurs. Coriaceous and glossy leaves, especially in tropical halophytes, are noteworthy, while in many salt-loving plants the stomata are sunken. Halophytes are found in our coastal salt marshes and on saline tidal flats in temperate and tropical countries and on the alkali flats of the interior of continents. Notable examples of these plants are the Salt Marsh Samphire, *Salicornia ambigua*, the Mangroves (*Rhizophora*) and the Bald Cypress (*Taxodium*).

Xerophytes.—The plants of this group, like the halophytes, are adjusted to live in a soil which is physiologically dry. The soil may owe this condition to its physical nature, such as porosity (sand), or to the presence of humic acids, or by chemical action, which inhibits the absorption of water. They are adapted to meet the conditions of strongest transpiration and most precarious water supply. To meet such conditions of physiological drought, the plants show various structural adaptations. In deserts, where the atmospheric precipitations are less than a certain limit, the plants acquire a xerophytic structure, such as succulency, water storage tissue, associated frequently with mucilage, lignified tissues, thick cuticle to the leaves, depressed stomata (frequently in pits), reduced trans-

piration surfaces and thorns. Mechanical tissues like wood and bast fibers attain their highest development in these plants. Cacti and the century plant (*Agave*) are types of xerophytes, while many bog plants like the cranberry and Labrador tea, with leathery leaves, are xerophytic.

Mesophytes.—These are plants that grow in soil of an intermediate character which is neither specially acid, cold or saline, but is sufficiently well supplied with water and rich in the elements required for plant growth. Plants which grow under such conditions do not have structures by which transpiration is closely controlled. They have large leaves frequently toothed and incised, with numerous stomata usually on the lower surface and small intercellular-air-spaces. The leaves and stems are usually of a fresh green color. Typical of the mesophytes are the grasses and most of the annual and biennial herbs of temperate regions.

Tropophytes.—This term was first introduced by Schimper in 1898 for land plants which have deciduous leaves and whose conditions of life are, according to the season of the year, alternately those of mesophytes and xerophytes. The mesophytic condition is found in summer, when the trees, shrubs and perennial herbs, included in this group, are in full leafage, and when, owing to the regular supply of rain during the growing season, the soil is plentifully supplied with water to meet the demands of these plants during the period of active transpiration. During the winter they are xerophytes. The cold of winter freezes the water in the soil so that the transpiration is reduced to a minimum, and this is associated with the fall of the leaves of the trees and shrubs and the death of the overground parts of the perennial herbs which spring up each year from their underground parts. The vegetation of cold temperate regions is mainly tropophytic.

The deciduous trees and shrubs, also known as the broad-leaved plants and the summer-green plants, form the principal tropophytes. The deciduous forests, which include the oaks, the beeches, the ashes, the maples, the walnuts, the chestnuts, cover a great part of eastern and western China, central Europe (England, France, Belgium, Germany) and eastern Australia, and are coincident with the countries occupied by the most civilized races of man, such

as the Americans, Europeans, Chinese and Japanese. The cold temperate climatic conditions which have determined the distribution of the forest trees have been influential also in the development of the energetic races of mankind.

FIG. 376.—A colony of the Golden Seal (*Hydrastis canadensis*), a tropophyte, growing in sparsely shaded woodland.

CARNIVOROUS PLANTS

The great and fundamental rôle of green plants in the world's economy is that of constructing highly complex organic compounds for food out of simple, inorganic, raw materials. This food, part and

parcel of their very bodies, is eaten by animals whose chief and contrasting rôle is that of breaking down the plant food into its simplest elements.

The raw materials which constitute the ordinary diet of green plants represent salts of various metals, such as nitrates, phosphates, sulphates, etc., the water which they absorb from the soil, and carbon dioxide which they inhale from the air during sunlight.

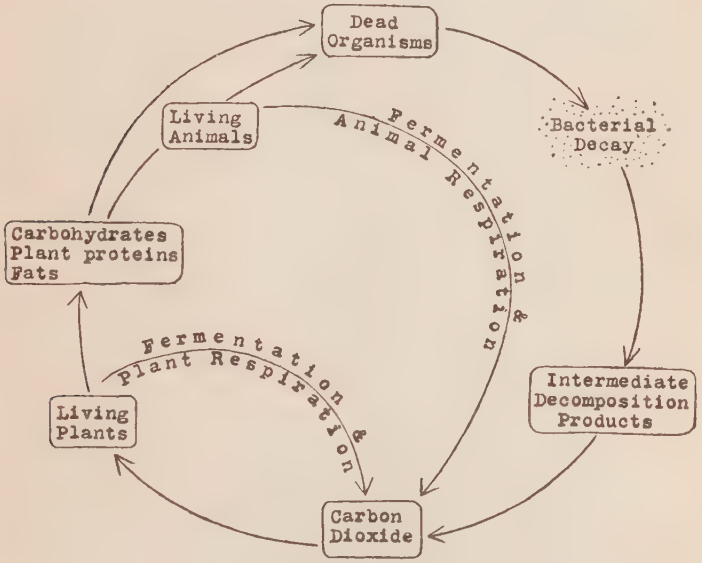

FIG. 377.—The carbon cycle. (*After Gager.*)

There exist, however, about 500 species of green plants which, in addition to the common habits of nutrition possessed by their relatives in the vegetable world, have acquired the luxurious appetite for the flesh and blood of animals. These exhibit a variety of devices for the allurement, capture, imprisonment, digestion and absorption of their prey.

Chief among these carnivorous plants are the sundews, fly-traps, pitcher-plants, bladderworts and butterworts. In each it is the leaves which have become modified for the purposes indicated.

The Sundews

The sundews are curious, small, bog plants that are mainly members of the genus *Drosera* which comprises 84 species, occurring in tropical, warm temperate and cool temperate regions of both hemi-

Fig. 378.—*Drosera rotundifolia*, the Round-leaved Sundew. (*From Jenkins' "Interesting Neighbors."*)

spheres. Each of these possesses a rosette of leaves that arise from a greatly reduced root system. The shape of the leaves varies depending upon the species, although it is frequently rotund, spatulate or filiform. The whole upper surface of the leaf-blade is covered

with glandular tentacles often of a wine-red color. The glandular heads of these are covered with a viscid secretion that glistens in the sunlight like dewdrops, a phenomenon that accounts for the common name assigned to the members of this group. The tentacles in the central part of the leaf-blade are short and erect and their stalks are green. Toward the margin they become longer and more inclined outward and their stalks are of a wine-red to purple color.

When examined under the microscope each tentacle shows a slender pedicel terminating in a gland. A conducting bundle containing spiral vessels and simple vascular cells is observed to come off of a fibrovascular bundle in the leaf-blade and run through the center of the pedicel to the gland. Upon entering the gland it is enlarged and spread out into a number of tracheids. These centrally placed tracheids are surrounded by a protective sheath (endodermis) outside of which are two layers of secretory (epidermal) cells with wine-red, granular contents, the outer layer of which is palisade-like. These glands are commonly oval excepting the extreme marginal ones which are considerably elongated. They secrete, absorb and are acted upon by various stimulants.

Darwin[1] has shown that when a small object is placed on the tentacles in the center of the leaf these transmit an impulse to the marginal tentacles. The nearer ones first respond and slowly bend toward the center and then those farther away until finally all become bent over the object. The time essential varies from 10 seconds to 5 or more hours depending upon the nature, contents and size of the object, upon temperature and also upon the age of the leaf. Again, if the glands are repeatedly touched or brushed or if chemical substances are placed on these, the marginal tentacles curve inward. The bending part of each tentacle is confined to a limited space near the base. Not only the tentacles but the blade of the leaf becomes much incurved when any strongly exciting substance is placed on the blade.

The time during which the tentacles and blade remain curved over the object varies according to the temperature, character of object, age, etc. Dr. Nitschke[2] found that during cold weather both the

[1] Darwin: Insectivorous Plants, p. 9, 1884.

[2] Darwin: Insectivorous Plants, p. 13, 1884.

blades and tentacles re-expand within a shorter period than when the weather is warm. Darwin[3] found that the tentacles remain clasped for a much longer period over objects which yield soluble nitrogenous matter than over those yielding no such matter. After a period varying from 1 to 7 days the tentacles and blade re-expand and are then ready to again respond. It has been shown by the same authority that as soon as the tentacles become inflected over an object yielding soluble nitrogenous matter their glands pour out an increased amount of secretion which becomes acid in nature. These glands, moreover, continue to secrete as long as the tentacles remain closely inflected.

In nature small insects catch sight of the glittering drops on the tips of the reddish tentacles and, mistaking these for honey, alight upon the leaf. They become instantly entangled by the viscid glandular secretion. They try to stroke the viscid fluid off of their legs but only besmear themselves more. Soon they become covered with the sticky substance which occludes the orifices of their breathing tubes (tracheæ) and they perish in a short time (one-quarter of an hour according to Dr. Nitschke) from suffocation. The surrounding tentacles bend over the insect's body and clasp it on all sides. A digestive juice containing a proteolytic enzyme of peptic character and an acid is now poured out of the glands. This digests the flesh and blood of the insects caught. The water-insoluble chitinous parts of the body are left on the surface of the blade. If the insect be large, the bending of the tentacles is augmented by the inflexion of the whole surface of the leaf-blade which assumes a concave shape. With the tentacles also curved over, the whole leaf simulates a closed fist. The glands then absorb the soluble nitrogenous material which is assimilated by the plant.

Among the insects caught by the sundews are gnats, flies, ants, beetles, small butterflies and dragon flies. The last named are captured by the cooperation of 2 or 3 adjacent leaves.

The Fly Traps

The fly traps comprise two species, viz.: the Venus Fly Trap (*Dionæa muscipula*) and the Submerged Dionæa (*Aldrovanda vesiculosa*).

[3] Darwin: Insectivorous Plants, p. 13, 1884.

The Venus Fly Trap is restricted to damp localities of a coastal plain strip extending for about 55 miles north and 45 miles south of

Fig. 379.—*Dionæa muscipula*, The Venus Fly Trap. (*From Jenkins' "Interesting Neighbors."*)

Wilmington, North Carolina, and nowhere over 15 to 20 miles in width.

Each plant shows a rosette of modified leaves which together are rarely more than 6 or 7 inches across. From the center of these arises a flower stalk bearing a cyme of white flowers which open from April to June.

Each leaf consists of a winged petiole that is studded on both surfaces with small, brown, stellate hairs. The petiole is truncated in front and contracted to the midrib which suddenly broadens out into a blade composed of 2 symmetrical halves that can fold together along the line of the contractile and irritable midrib region. Along the margin of each half of the blade are long, stiff, non-irritable bristles which, on closure of the blade, interlock with each other. On the center of the upper surface of each half of the blade are three spine-like, sensitive hairs disposed as angles of a triangle. Each of these sensitive hairs is composed of elongated cells whose protoplasmic contents show movement. At the base of each is a cylindrical mass of small cells which permits the stiff hair to be bent over. These sensitive hairs are highly irritable and capable of receiving and transmitting a stimulus. Further, over the entire upper surface of the blade are numerous, closely set, sessile, glandular hairs which, after repeated irritation, secrete an acid digestive juice. Each of these, as observed under a microscope in surface view, consists of a rosette-arranged set of cells composed of 4 to 12 cell radii filled with a crimson-claret pigment.

Each sensitive hair consists of a somewhat elongated structure composed of 3 parts, viz., base, highly sensitive joint and insensitive shaft. The base consists of large epidermal cells enclosing a prolongation of mesophyll cells within, that can receive and propagate a stimulus from the sensitive joint to the leaf interior. The joint consists of elongated columnar cells that enclose similar columnar mesophyll cells with soft, elastic walls. The shaft cells are elongated, thick-walled and almost insensitive.

When a stimulus is applied to any sensitive hair, this affects the joint cells and causes upsetting of turgidity and exudation of liquids with a consequent contraction of the elastic cells. The action is propagated to the midrib region where the cells, by contraction along the upper surface and expansion along the lower, cause closure of the halves.

Macfarlane[1] has shown that when an insect alights on a leaf of Dionæa, one hair must either be stimulated twice or 2 hairs on the same leaf at slight intervals apart in order to cause closure. The caught insect produces a summation of stimuli and gradual tightening of the lamina occurs under the repeated stimuli until the halves become closely locked. The glandular hairs now pour out an acid digestive secretion which digests the flesh and blood of the insect's body. The soluble nitrogenous substances are then absorbed by the glands and assimilated.

Dr. J. S. Hepburn[2] recently found that the secretion of the leaves of *Dionæa* contained a protease which was active in the presence of 0.2 per cent. hydrochloric acid. This enzyme, therefore, resembles pepsin of the gastric juice of man, which also acts in a 0.2 per cent. hydrochloric acid medium.

Dr. J. M. Macfarlane, who with Dr. Canby and Charles Darwin have separately investigated the structure and physiological activities of this plant, reports that 2 touches one-fourth to one-third of a second apart will not produce closure of the halves, though a second stimulus that is from 1 to 120 seconds apart from the first will effect closure, also that it is not essential for the stimulus to be on one hair, that a prick sets off the trap at once due to liquid escaping from turgid cells and, further, that all muscle stimulants, mineral acids and ammonia effect closure of the trap.

Among the insects caught by *Dionæa* are earwigs, millipedes, flies, ants, wood-lice and dragonflies. The length of time required for the digestion of their softer parts and the absorption of the soluble products of digestion varies. During this time the trap remains closed. Darwin[3] cites 4 instances in which leaves after catching insects never reopened but began to wither. Mrs. Treat,[4] who made observations on plants cultivated in New Jersey, noted that "5 leaves digested each 3 flies and closed over the fourth, but died soon after the fourth capture." The power of digestion possessed by *Dionæa*, accordingly, is more limited than that of

[1] Macfarlane: Contrib. Bot. Lab. U. of Pa., 1: 7–44, 1892.
[2] Hepburn: Jour. Franklin Inst., 194: 780, 1922.
[3] Darwin: nsectiv. Plants, p. 309, 1884.
[4] Treat: Insectiv. Plants by Darwin, p. 311, 1884.

Drosera, which has been known to capture and digest many insects in a shorter period of time.

Aldrovanda vesiculosa, which might well be called a "Submerged Dionæa," is a relative of the Venus Fly-Trap. It is a floating aquatic plant found widely distributed in shallow ditches and ponds over the old world from Europe to Australia but nowhere abundant. This plant is entirely devoid of roots, but possesses a slender stem which bears whorls of modified leaves at its nodes. Like the Venus Fly Trap, each leaf shows differentiation into a winged petiole ending in 5 narrow processes that connect with a terminal, rounded, incurved blade, divided into equal halves by a sensitive midrib, but the midrib projects beyond the summit of the lamina as a bristle. Long, rigid, spiny bristles extend from the petiole and are thought to prevent the approach of animals unsuitable as prey. The margins of each half of the blade are bent inward and their rims are studded with short conical teeth. Projecting from the upper surface of the midrib and along a line describing the inner third of the upper blade surface are a number of sensitive hairs and short-stalked, disc-shaped, glands while over the outer portion of the surface are to be noted a number of scattered stellate hairs.

Larvæ of aquatic insects and small species of Crustaceans such as *Cyclops*, *Daphnia* and *Cypris*, swimming by, occasionally brush against the sensitive hairs and the 2 halves of the blade close together just as in *Dionœa*, and the animals are entrapped. When they attempt to escape through the place where the margins of the blade meet, they find the conical teeth prevent their egress. They die in the trap, and when the latter are forced open and examined a couple of weeks later they only contain the chitinous skeleta.

The Pitcher Plants

The pitcher plants are for the most part found in bogs. Their main representatives belong to the genera *Heliamphora*, *Sarracenia*, *Darlingtonia*, *Nepenthes* and *Cephalotus*. The pitcher itself represents the hollowed out midrib of the leaf in the first four named genera and an inpouching of the leaf in the last named genus.

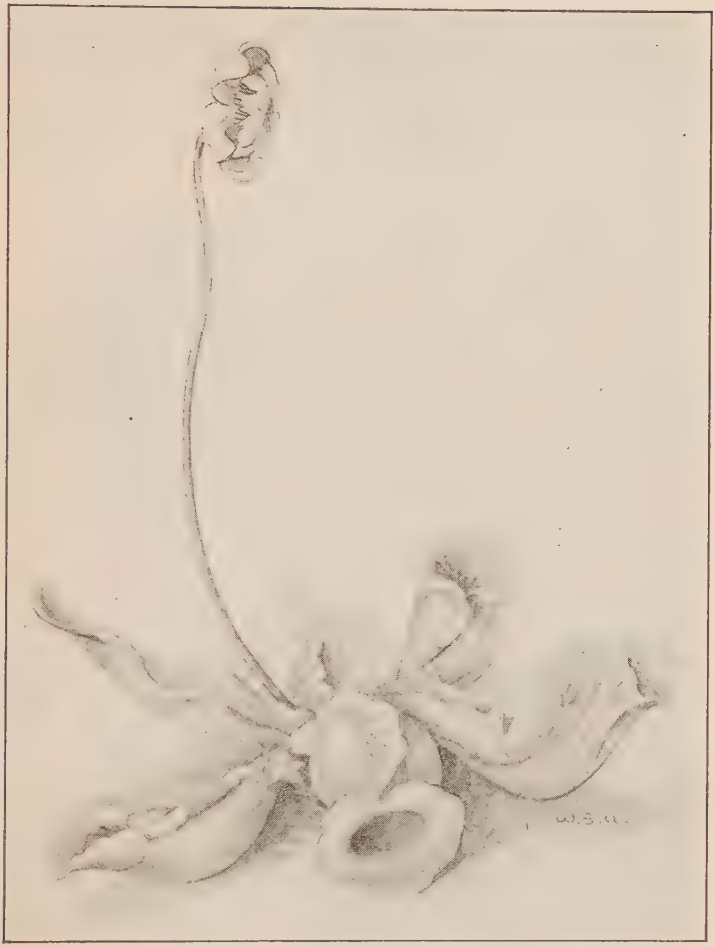

FIG. 380.—*Sarracenia purpurea*, a pitcher plant from a northern bog. (*From Jenkins' "Interesting Neighbors."*)

Heliamphora[1] is represented by a single species (*H. nutans*) which is only found on and around the base of Mount Roraima, between British Guiana and Venezuela. Here it flourishes in wide-spreading dense tufts in wet places where the grass is short. It has a rosette of red-veined pitcher-leaves and delicate white flowers raised high on red-tinted stems. Along the entire length of the pitcher are 2 broad wings. The pitcher itself represent a hollowed out midrib which is tubular in shape, becoming gradually broader from base to mouth and ending in a small lid. Over the entire outside of the leaf are nectar glands and upward directed hairs. The nectar glands secrete a sweet fluid which entices insects so that this surface can be termed the alluring surface. Nectar glands also occur on the inner surface of the lid. Next, the upper one-third to one-half of the inner surface of the pitcher is covered with downwardly projecting hairs and nectar glands. This surface can be called the attractive and conducting surface. A smooth surface follows, which in turn is succeeded by a detentive surface in the lower part of the pitcher, composed of mostly smooth-walled cells, a few of which bear short hairs.

Sarracenia[1] is represented by 7 species all of which are confined to Eastern North America except *Sarracenia purpurea*, which extends west to Western Minnesota and West Central Canada. Their pitchered leaves are of varying form and color design, depending upon the species. Frequently they are long funnel-shaped, tubular or vase-shaped. The color of every species varies with its age as well as extent to which it is exposed to bright sunshine. In some respects the form of pitchers resembles *Heliamphora*, but there is only a single wing present and further the lid is considerably larger.

In all we find the pitchers showing an alluring outer surface covered with nectar glands, but devoid of the upwardly directed hairs seen in *Heliamphora*, an attractive inner lid surface, marked with numerous downwardly directed hairs and nectar glands which lead the insect toward the next or conducting surface. This is either nearly smooth (*S. purpurea*) or presenting delicate, downwardly projecting processes and on which the insect loses its foothold, also

[1] Macfarlane: *Sarraceniaceæ* in Engler, Das Pflanzenreich, 34 Heft, (iv, 110) 39 pp., 1908.

(excepting *S. purpurea*, which next shows an intervening glandular zone) a lower dententive zone, in the bottom of the pitcher, which contains a watery fluid and whose surface, save its lowest portion, is marked by the presence of many elongated, downwardly directed, thick-walled hairs, which prevent the ascent of insects that have fallen into this zone from above. Glands are also present on the upper part of the detentive surface.

FIG. 381.—A colony of *Sarracenia purpurea* growing along the border of a pond in Burlington County, New Jersey. *Chamæcyparis* in background.

Darlingtonia[1] is represented by a single species, *Darlingtonia californica*, which grows in mountain swamps and borders of small streams at altitudes of 1000 to 6000 feet from Plumas county in the Sierras of California northward to Jackson and Josephine counties in Oregon. Its underground rhizome gives rise to pitchered leaves

[1] Macfarlane: "Sarraceniaceæ," in Engler, *Das Pflanzenreich*, Heft (iv, 110), 39 pp., 1908.

FIG. 382.—*Sarracenia flava*, a pitcher plant from a North Carolina bog. (*From Jenkins' "Interesting Neighbors."*)

which are from 1½ to nearly 3 feet in height and spirally twisted in about a half revolution. Each pitcher expands near the summit

FIG. 383. Darlington's Pitcher Plant (*Darlingtonia Californica*) from mountains in California. (*From Jenkins' "Interesting Neighbors."*)

into an inflated hood which exhibits a circular opening up to an inch in diameter on the under side. The dome of the hood is spotted with

large, thin, translucent areas. A wing extends along the pitcher from rhizome to its orifice. At the upper and outer edge of the opening is a moustache-shaped appendage which possesses stiff hairs all of which point toward the pitcher opening. The color of the pitcher is green, blotched with red and yellow. Within and about the open-

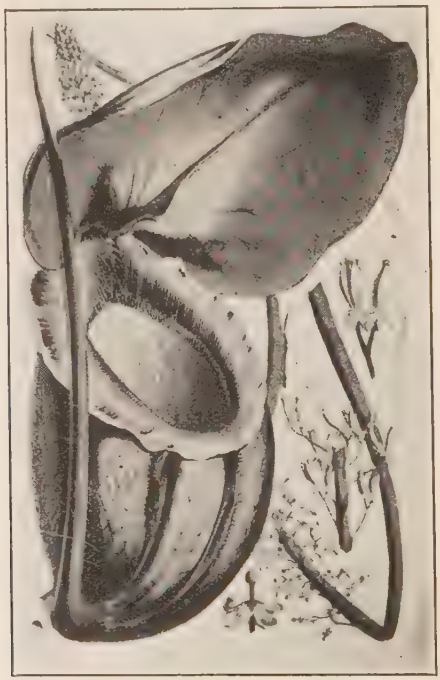

FIG. 384.—*Nepenthes Rajah.* (*From St. John's "Life in the Forests of the Far East."*)

ing and on the bi-lobed appendage are alluring glands which secrete a nectar attractive to insects. The nectar is also secreted by glands along the wing. An insect creeping over the exterior of the pitcher is enticed to the nectar along the wing which it follows up to the orifice where the honey is sweetest. Flying insects are attracted to the pitcher by its mottled and colored features. They alight on one of the flaps of the appendage and follow its curve which narrows

to the orifice. Sharp bristles in the path pointing toward the orifice make it the natural direction for the insect to travel. Upon reaching the end of the path, it is tempted farther by honey glands within the opening of the pitcher which it next visits. When satisfied and ready to leave, the translucent areas on the hood above, like illuminated windows, entice it from the opening by which it entered. The insect sees no means of escape, nothing but hairs on the inner surface of the pitcher pointing downward and which direct it to the dark detentive pit below, where it drowns in the watery secretion.

By far the most beautiful and gracefully shaped pitchers are those belonging to the genus *Nepenthes* which is represented by about 68 species that are mainly indigenous to the East Indies with headquarters in North Borneo and with Mount Kina Balu as a center. Many of the plants are continuously exposed to a moist dripping atmosphere.

Each of the modified, pitchered leaves shows a petiole (usually winged) which widens into an expanded blade, the midrib of which is continued as an elongated tendril which expands into a terminal winged pitcher. The pitchers show a large variety of shapes and color designs depending upon the species. Frequently they are tubular, goblet or cornucopia shaped. Each pitcher has a hinged lid which varies from small elliptic to large heart- or kidney-shaped. The tendril is sensitive to contact stimuli and often winds about a limb of a tree. The pitchers, partly filled with a viscid watery secretion, either hang suspended in the air from the tendril or rest on the ground.

One of the largest pitchers found in this group is that of *Nepenthes Rajah*, a species found on Mount Kina Balu along the north coast of Borneo at an altitude of 5000 feet. It has leaves which, exclusive of petioles, are 18 inches long, and the pitchered portion is 6 inches in diameter and 12 inches in length with a circumference of 19 inches. The lid is 10 inches long and 8 inches broad. The pitchers rest on the ground in a circle. The color of the pitchers is deep purple. The color of the lid portion is lavender, shading to green at the edges. One pitcher noted by Spenser St. John[1] held 4 pint bottles.

[1] St. John, S.: Life in the Forests of the Far East, 1: 334, 1863.

Nepenthes Edwardsiana, another large pitchered form reported by St. John,[1] is an epiphytic climber found on the north side of Mount Kina Balu at altitudes of 6000 to 8000 feet. One plant measured by this explorer was 20 feet long and had a large cylindrical pitcher on every leaf, 21½ inches long and 2½ inches broad. The base of the pitcher was bright pea green, the remaining surface a brilliant brick-red. The circular lid was red in the center and green around the margin.

The lower surface of the petiole, lamina and the whole external surface of the tendril and pitcher are covered with alluring nectar glands. These alluring glands also occur along the stem. Their secretion entices insects to the pitcher mouth or lid. Around the mouths of the pitchers of nearly all of the species is a corrugated rim on which are parallel ridges, which are usually extended as teeth that are inclined downward into the pitcher cavity. The surface of this rim is smooth and polished, so affording a poor foothold for insects. Around this rim, in the region of the teeth, are the openings of deeply sunken, marginal glands which pour forth a very sweet nectar, attractive to insects. The inner surface of the lid is usually dotted with attractive glands.

In many species of *Nepenthes*, the entire inner surface of the pitcher cavity constitutes the detentive surface. It is lined with a smooth epidermis that is uniformly studded with glands which secrete a digestive juice containing a proteolytic ferment and absorb the soluble products of digestion. In many others the upper surface of the cavity is smooth, forming a conducting surface, while the lower one-half or one-third is alone detentive. Insects lose their foothold on the conducting surface and fall into the watery secretion at the bottom of the pitcher.

Cephalotus has but one species, *C. follicularis*, which is native to swamps of South West Australia. It has short creeping rhizomes which produce annually one set of 5 foliage leaves and later a set of pitcher leaves which rest on damp soil. The pitchers externally are equipped with winged ridges which provide a handy means of ascent to the mouth for creeping animals, while their lids are half-closed and mottled with white areas and purple veins and are often

[1] St. John, S.: Life in the Forests of the Far East, 1: 335–336, 1863.

mistaken for flowers by high flying insects. In minute details of structure the pitchers are surprisingly like those of *Sarracenia* and *Nepenthes*. The exterior of the stalk is studded with alluring glands. The margin of the pitcher is corrugated and inflexed and all over this area and exterior of corrugation as well as on the inner lid surface are an abundance of honey glands (attractive surface). Just inside of the margin is a circular shelf-like ingrowth consisting of downward-directed cells which resemble the conductive surface of *Sarracenia*. The remainder of the inner surface constitutes the detentive surface. At the bottom of the pitcher on either side are two beautiful crimson to crimson-claret patches. These have sunk in them huge, many-celled glands which have a fibrovascular bundle terminating in their base. The glands secrete an acid digestive juice which partly dissolves the animal captives. A viscid secretion partly fills the pitcher cavity.

As to relations of the pitchers of these several types of curious plants to animals, it may be said that insects, spiders, etc., are attracted to the plants partly by the brilliant colors of their pitchers and partly by the nectar drops exuded by honey glands. They make their way to the exterior of the lid (or appendage in *Darlingtonia*) where the secretion along the outer margin is plentiful. From here they move to the inner surface of the lid and sip the honey. Tempted further by the sight of nectar ahead and often by hairs pointing downward, they step inside the pitcher on to the conducting surface. Upon reaching this surface they waver, slip off and fall into the lower part of the pitcher which is the water holding region. They make numerous attempts to escape but find exit impossible on account of the downward-projecting hairs. They drown in the liquid and their bodies are either decomposed or digested by a digestive juice secreted by glands lining the lower portion of the pitcher cavity.

The animals caught by these pitcher plants are various. While insects constitute their chief prey, slugs, spiders and rodents have been recorded by observers as having been captured by a number of them. Burbidge[1] observed several Nepenthes in North Borneo visited by a small rodent, which, while perched on the margins of

[1] Burbidge: Gard. of Sun, pp. 40–344, 1880.

the pitchers bends its head and neck and scoops out the caught insects and devours them. The same writer states that if it attempted such action with *N. bicalcarata*, the two sharp spurs with which the pitcher of this species is provided catch it by the neck and tumble it into the pitcher.

FIG. 385.—*Nepenthes Edwardsiana.* (*From St. John's "Life in the Forests of the Far East."*)

Macfarlane[1] has carefully observed the relations of *Nepenthes* to animals. He states in part that "running insects such as ants and cockroaches are their principal prey. Cockroaches run up the stem and may pause to sip nectar from the alluring stem glands. Reach-

[1] Macfarlane, Nepenthaceae, in Engler, Das Pflanzenreich, 36 Heft, 88 pp., 1908.

ing the base of the leaf, they may pass along it, attracted by the presence of honey drops there. They almost invariably run along its under side to shelter themselves from enemies and the hot sun. Moving on restlessly and sipping from nectar glands as they advance, they reach the tendril. The ventral wings and the areas between are more beset with alluring glands than is the outer part of the pitcher and along this they often run till they reach the orifice or lid. The lid glands of the inner surface prove a great attraction but their secretion does not compare with the marginal glands. Straining to reach the orifices of the glands, the insect visitors often overreach themselves after a few efforts and tumble into the pitcher cavity, and in rare cases is escape again possible."

Mr. Low who accompanied Spenser St. John on his travels in North Borneo found a drowned rat in one of the pitchers of *Nepenthes Rajah*.[1]

The character of the enzymes found in the pitcher secretions has been investigated by Hepburn.[2] This author found a tryptic enzyme in *Nepenthes* which was active in a slightly acid medium. No proteolytic enzyme was found by him in the secretions of *Darlingtonia* while the Sarracenias he investigated were found to possess proteolytic enzymes. The protease in the pitcher liquor of *Sarracenia flava and S. minor* acts best in 0.2 per cent. hydrochloric acid while that present in *S. purpurea, S. rubra, S. Sledgei* and *S. Drummondii* acts best in an alkaline solution containing 0.5 per cent. or less of sodium carbonate. Dakin[3] found a protease in the pitcher liquor of *Cephalotus*.

The Bladderworts

The bladderworts belong to the genus *Utricularia*. They are aquatic plants which are found in pools and bogs of various parts of the world with their centers in S. America and the East Indies.

The plants are rootless and according to the season of the year sink to the bottom or rise to near the water surface. They have finely dissected submerged leaves, some of which are specialized as bladder-

[1] St. John, S.: Life in the Forests of the Far East, 1: 335–336, 1863.

[2] Hepburn, St. John and Jones, Jour. Frank. Inst., 189: 152, 1920.

[3] Dakin: Jour. and Proc. Roy. Soc. W. Australia, 4: 37–53, 1919.

like traps which allow the entrance but not the escape of small animals. Each of the traps represents a greatly modified, inflated leaf of vesicular form and usually about $\frac{1}{16}$ to $\frac{1}{5}$ inch in diameter.

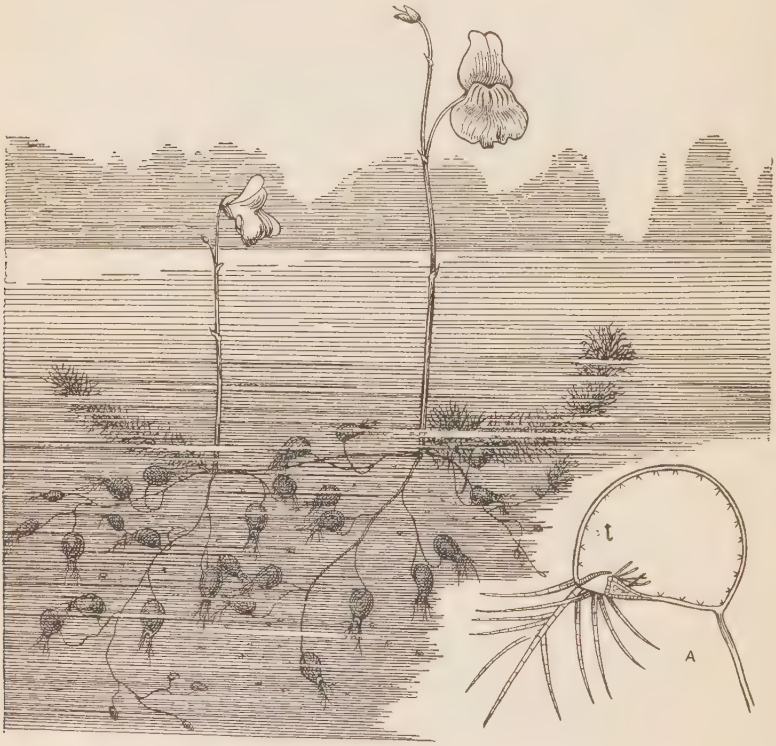

FIG. 386.—A Bladderwort (*Utricularia Grafiana*). Note the submerged stems bearing modified, bladder-like leaves. Small animals become entrapped in these bladders where they are decomposed and the water-soluble portions of their remains are absorbed as nourishment by the plant. In the lower right-hand corner is a bladder-like leaf of another species (*Utricularia neglecta*) shown in section. The entrance to the bladder is protected by numerous hairs and by a trap door (t). Drawing based upon Kerner. (*Gager.*)

From the margin of its opening project stiff bristles. There is an upper and lower lip present. The lower lip is greatly thickened and provided with a cushion-like process that extends into the bladder.

From the upper lip is suspended a thin elastic valve, the free edge of which rests upon the inner surface of the lower lip cushion and closes the opening.

Small animals, including crustaceans like *Cyclops* and *Daphnia*, as well as larvae of small insects and worms, enter the bladders either because they seek a sheltered harbor for a time from larger prey or because they expect to find food within the bladder. In entering they have to press upon the valve and push it back. As soon as they stop pressing upon the valve, the elastic character of the valve causes it to close by bringing it back on the under lip cushion. The entrapped animals struggle to escape by pressing themselves against the valve, but their efforts are in vain, for it is impossible for the prisoners to force the valve outwardly over the cushion, and they die in time either from starvation or suffocation. Their bodies decompose and the water-soluble products of decay are absorbed by quadrifid cells lining the entire inner wall of the bladder.

The Butterworts

The Butterworts comprise an interesting group of flesh-eating plants which are placed in the genus *Pinguicula*. About 40 species exist of which probably the best known is *Pinguicula vulgaris*, a member of the *Utriculariaceæ* which occurs in bogs or other damp places generally in mountainous districts of northern North America and Europe. Each plant exhibits a root system of from about 5 to 16 short, submerged, unbranched roots from which arises a rosette of oblong-ovate, yellowish-green leaves, the younger central ones being concave and more or less erect, the older marginal ones being flat or convex with their lower surfaces resting upon the moist ground. From the center of the leaf rosette there arises a slender scape bearing a single flower of violet blue hue that is spurred in its corolla portion.

Alike with other investigated species of *Pinguicula*, the leaves of this plant have somewhat upturned margins which give them the form of a broad trough the upper surface of which is covered with a viscid secretion. Microscopical examination of this surface discloses 2 types of glands (excepting along the margin), the first being of

toadstool shape and consisting of a cylindrical stalk bearing a disc-shaped head of 8 to 16 cells arranged radially, the second consisting of a shorter stalk bearing an 8-celled head.

Darwin[1] and others have experimented with the leaves on living plants of several Butterworts and found that drops of water, gum or sugar, and scratching of the surface of these leaves produced no response, that insoluble solid bodies such as grains of sand and powdered glass allowed to remain for some time caused slight incurving of the margins and a slight increase in the quantity of mucilage secreted by the glands, but that when nitrogenous bodies such as bits of cartilage, meat, clotted blood, etc., are placed near the margin in contact with the glands they are excited and pour forth abundant mucilage and an acid secretion. Moreover, prolonged contact with these bodies caused a marked incurving of the margin which pushed them slowly toward the middle of the leaf where more glands are present and so increased secretion. This acid secretion completely dissolved these substances which were later absorbed by the leaf.

An idea of the time necessary for the secretion of fluid and the digestion and absorption of nitrogenous bodies by these leaves may be gained by the experiment of Darwin with 3 small cubes of tough cartilage from the leg-bone of a sheep (see Insectivorous Plants by Chas. Darwin, p. 382, 1884).

"Within 10 hours and 30 minutes some acid secretion was evident but the cartilage was little or not at all affected; after 24 hours the cubes were rounded and considerably reduced in size; after 32 hours they were softened to the center and one was liquefied; after 48 hours a trace of only one of these was evident and after 82 hours all 3 cubes were liquefied, the secretion was entirely absorbed and the glands were left dry."

When small insects alight from the air upon the leaf of the butterwort, they become fastened by the mucilage and in struggling to extricate themselves only become deeper enmeshed by it. Within a short time the acid juice, secreted by the glands as a result of the stimuli, digests their bodies and all excepting their hard, indigestible outer skeleta (exoskeleta) is absorbed.

[1] Darwin: Insectiv. Plants, pp. 371–390, 1899.

If small creeping insects come upon the margin of the leaf they stimulate the edge to curl over and the marginal glands to secrete. While the insect is enmeshed within the adhesive mucilage, it is slowly pushed by the curling up of the edges into the middle of the leaf where the acid secretion glands are most abundant. In about 24 hours the softer parts of its body are digested and absorbed and the leaf expands to its normal condition.

Significance of the Carnivorous Habit

In all of the animal-eating plants which have been investigated structurally and chemically, sufficient evidence has been recorded to warrant the conclusion that these forms have developed their peculiar habit and correlated structures with the object of providing adequately for their nutrition.

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